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THE EFFECT OF THE RECENT DROUGHT ON SOUTH DAKOTA PUBLIC WATER SUPPLIES

By E. G. Fiala

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The lack of precipitation, coupled with high temperatures and hot winds, has produced the most severe drought in the climatological history of the State of South Dakota. Unprecedented dust storms were experienced during the past season, and as a whole the agricultural sections of the state report a complete loss of crops. Next to 1931, 1933 was the hottest and driest year in the history of the State; 1921 was equally as hot and 1894 was equally as dry. The worst dust storm occurred on November 12, 1933. As in other states in the midwest, an appreciable effect upon the water supplies, particularly those supplies derived from surface and shallow well sources, was noted.

In reviewing the precipitation record of the state it is noted that less than one-half of the normal rainfall was received during the first five months of this year. The normal rainfall for South Dakota is about 21.6 inches per year. In a nine months period (September, 1933 to May, 1934) an average of only 4.7 inches of precipitation was recorded. In June, however, the return of precipitation temporarily broke the severe drought that had prevailed since September, 1933, an average of 3.35 inches for the month being recorded from reports of 99 stations.

Further examination of the records shows the present drought may have been caused by an accumulated deficiency in rainfall for the

past five years. The results of the deficiency have caused an extensive depletion of streamflows over the entire state. Many of the smaller streams are exceedingly low or dry at the present, and the major streams have an average flow of less than 10 percent of the normal flows. The James River (the largest in the eastern part of the state) is dry at present in the vicinity of Huron, and at different points along its course the river has reached the "pool" stage.

The lakes of the state also show a very decided effect of the drought. Fifteen of the most important lakes in the state are dry or very low. These include such lakes as Blue Dog, Cottonwood, Poinsett, Kampeska, Lake Waubay, Rush Lake and Lake Andes. Most of these lakes have an average depth in normal times of 8-10 feet. The other smaller lakes of the state, of course, are bone dry.

A very similar situation exists with the rivers. Such streams as the Grand, Moreau, Cheyenne, White and Jim rivers have ceased to flow or have reached the pooling stage. One is safe in saying that the only major streams in the state flowing at present are the Missouri and Big Sioux.

The prolonged series of subnormal precipitations, followed by the present drought, has resulted in a continual lowering of the ground water levels. This lowering is noticed by the increase in pumping heads, decrease in pressure of flowing wells and the failure of spring supplies. The failure of the springs has also had an appreciable effect on stream flows as many of the smaller streams in the state have as their source the excess flow from these springs.

The municipalities and individuals experiencing the greater difficulties in water shortage are those depending upon surface reservoirs, streams, lakes, springs and shallow wells. There are 14 cities and towns dependent upon surface supplies and 15 cities and towns deriving their supplies from springs. Of these numbers, 4 cities having a combined population of more than 40,000 are now making arrangements to develop ground water supplies.

GEOLOGY OF THE STATE

In discussing the effect of the drought on the South Dakota water supplies, it is perhaps well to review briefly the geology of the State. The thick succession of sedimentary formations underlying South Dakota includes porous strata usually containing large volumes of water. These water bearing deposits comprise widespread sheets

of sandstone or sand ranging from the Cambrian to Tertiary in age, the alluvial sands in the bottoms of valleys, and the sands of the sand hills. The sandstones are, in many places, several hundred feet thick and lie between bodies of relatively impermeable shales or limestones, so that these present favorable conditions for artesian waters. To the west they are upturned on the uplift of the Black Hills and outcrop at high altitudes. To the east some of them come to the surface and others thin out.

Part of the rainfall and stream flows pass into the sandstones in their elevated regions and flow eastward through the rock in its extensions under the lower lands. Some of the water finally escapes in springs in the outcrop in eastern South Dakota and Nebraska. In such water bearing strata as the Dakota and other underlying sandstones, which are overlain by a thick mass of impermeable deposits, these waters are under great pressure, by virtue of the elevation of the intake zone. This region has an elevation of about 4000 feet and the region of outflow is only 1000–1200 feet above sealevel. The evidence of this pressure, as found in many eastern wells, is conclusive that the water flows for many hundreds of miles. Several deep wells in central and eastern Dakota showed at one time a surface pressure of 200 pounds per square inch. If it were not for the outflow of the water to the east and south the initial head which the waters derive from the high lands of the intake zone, would continue under the entire region, but owing to this leakage the head is not maintained and there is a gradual diminuation toward the east known as the "hydraulic grade." Other factors which undoubtedly influence the hydraulic grade is the unknown amount of leakage through the so-called impermeable strata, all of which permit passage of water especially when under great pressures and the friction losses through the formation. For the past several years the static heads on many of the eastern flowing deep wells has gradually diminished to such extent that most wells are flowing under a greatly reduced pressure, if at all.

This gradual lowering in the static heads may also be accounted for by the fact that the western exposures of the water bearing formation cover a relatively large area which is normally crossed by many streams. These streams in crossing the formations give up about 50 percent of their flow. The lack of sufficient precipitation in the west region is unquestionably an important factor. The average

normal precipitation in the Black Hills district is about 25 inches per year, and the recorded precipitation since September, 1933 is much less than the normal.

WATER HORIZON

The Dakota sandstone is the most widely extended and serviceable water bearing formation in South Dakota and it is the principal source of artesian flow in many wells. It consists largely of sandstone and averages about 300 feet in thickness. The sandstone is in thick sheets separated by deposits of clay or shale.

In the Black Hills there are two water bearing sandstones, separated by a shale, known as the Fuson formation which separates the Dakota sandstone above from the Dakota sandstone below. To the east these formations thin out and in the eastern part of the state the Dakota sandstone lies on the Sioux Quartzite or granite, except in the most southeasterly portion where limestones and other rocks intervene. The Dakota water horizon is believed to underly the entire state with the exception of a small area in the eastern part of the state in the vicinity of Mitchell. At this point there is a quartzite uplift, at which the Dakota formation terminates, appearing again immediately to the east of this uplift. From the quartzite uplift the dip of the sandstone is quite rapid in all directions for a short distance, but gradually diminishes away from this ridge until the formation is nearly horizontal.

Other water bearing formations of the state are the Pierre shale, Chalkstone and Benton shale and sandstone. The Benton group consists mostly of shale, but beds of sandstone containing more or less water are noted in the eastern part of the state. Some artesian wells derive their flow from the Benton group. The principal water bearing sandstone in this group is a bed which occurs near or at the top of the formation. In some places it immediately underlies the Chalkrock formation. The upper sandstone of the Benton is only about 25 feet thick, and the greatest thickness attained is 85 feet. However, due to its coarseness in structure it is capable of producing moderate quantities of water.

There are other local deposits of water bearing strata which supply water for deep wells. The area of exposure, however, is usually quite small and due to the limited precipitation they cannot be depended upon to yield any appreciable quantity.

The shallow wells supplies are derived from water bearing strata

lying near the surface of the ground, usually glacial deposits of gravel or glacial till, or gravel deposits found in the valleys or lake beds. The recharge of these wells is largely dependent upon precipitation or seepage from nearby streams or lakes; consequently with subnormal precipitation the yield of these wells is very questionable.

No common geological formation can be named as the predominant source of supply for shallow wells. However shallow wells supplying the greatest amount of water derive their supply from gravel deposits in valley flows of the larger streams. These water producing gravels are greater in extent and more common in the Sioux River valley than any other lowlands.

The glacial moraines in the northeastern part of the state consisting of gravel, boulders, clay and till may be expected to yield a moderate supply of water. In some places large areas of sand and gravel exist and it is from these deposits that most water is likely to be obtained.

As is shown there are several sources of underground water in South Dakota, but the Dakota sandstone, associated with the other sandstones, furnishes the bulk of the supply for the State's needs. In these formations a very large number of flowing wells have been sunk, most wells being in the eastern part of the state. The aggregate flow of the wells was estimated to be about 7,000,000 gallons per day.

It is believed by some persons that this great draft is diminishing the available supply and from information obtained on loss of flows and reduced pressures of existing flows there may be some truth in the statement. There are, however, a large number of factors that may contribute to the decrease in head, namely, leakage, clogging and interruption by an increase in number of new wells.

At a time like this there is an increased draft on many of the more reliable supplies to provide water which normally would be obtained from surface sources or shallow wells which are failing, and also to supply the increased consumption from water works for sprinkling lawns and other purposes. Thus there is likely to be an over-draft in these perennial wells beyond their normal capacity or beyond the normal capacity of the pumping equipment. The resulting trouble may be widely heralded as evidence that even the most reliable sources are failing or going dry.

The entire area of South Dakota is underlain by water bearing formations, which constitute large underground reservoirs which

can be reached for municipal domestic and livestock use to meet the emergency. The problems, however, involve the time and the cost required to develop the source.

While making a limited number of personal contacts with water works officials, the writer learned there is a reduction in ground water levels from 7 to 30 feet depending upon the source of supply. For the most part the greater reductions were noted in shallow wells, and in wells where the artesian water was not reached during drilling. In a number of instances wells were reclaimed simply by cleaning and drilling a few feet deeper.

EXPERIENCES DURING DROUGHT

For this paper the various water works superintendents and city officials kindly furnished recent data on wells and ground water. About 185 questionnaires were sent out asking for information relative to each particular supply, as to source, location, pumpage, per cent of population served, number of wells, type, diameter, depth, date installed, depth to water when new, drawdown when new, present depth to water, present drawdown, seasonal fluctuations in yield, adequacy of supply and an opinion on the lowering of the ground water level. Approximately one-third of the questionnaires were returned.

Checking over the results, 20 reported no lowering in ground water level, 30 reported yes, the distance varying from several to as many as 90 feet. One municipality reported an increase in flow of 100 per cent, while 9 did not comment. Taking the results into consideration one would think the lowering of the ground water levels is merely a matter of opinion, while as a matter of fact of the 20 reporting no lowering, 14 have supplies taken from wells more than 250′ in depth and having a pumpage of less than 100 g.p.m. and all of the water from these wells is metered. On the other hand, of the 30 reporting a lowering, 11 have supplies from wells more than 250 feet in depth and have a pumpage of less than 100 gallons per minute and all water metered except one. The other 19 supplies are taken from wells ranging from 18 to 250 feet in depth and have a pumpage exceeding 200 and up to 800 gallons per minute. Other municipalities reporting no effect are those having a deep well and an exceedingly low pumpage. For example, one municipality reporting no lowering has 4 wells ranging from 160 to 260 feet in depth and has a pumpage of 10 gallons per minute from all wells. Another having a well 1900

feet deep with a pumpage of 6 gallons per minute reports no lowering and probably a rising. Instances such as these, of course, cannot be considered entirely reliable due to such small quantities of water required for the communities needs. Any slight lowering in these supplies may produce very disastrous results. It will be noticed that the greater fluctuations reported are those from wells located in the eastern part of the state within the Jim River valley and taking their supply from the artesian basin. The questionnaires bear out conclusively that there is a change in the ground water levels and that shallow wells respond quickly to seasons of drought or heavy rain. They also show the unreliability of shallow wells for municipal supplies. This is probably more true in Dakota than in other states of the mid-west, although the statement holds also for western and southern Iowa.

The greater part of the rainfall in South Dakota occurs during crop growing seasons (April to September) so we have November, December, January and February confronting us with little signs of precipitation. It is true, however, that each rainfall during these months will contribute water to the soil zone until the present deficiency is satisfied, the excess, if any, will then penetrate to the water table. During the winter months, however, this process is interrupted by the freezing of the ground and the accumulation of snow. Therefore, it is likely that the heaviest ground water recharge will occur in the early spring months with the melting of the snow and an expected increase in precipitation.

DANGERS TO PUBLIC HEALTH

The dangers encountered in times of drought from a public health standpoint are far more severe than are realized. A continual lowering of the ground water levels has a very decided effect on the water from a bacterial standpoint. As the water recedes, pollution from near the surface is carried deeper and eventually enters the main source of supply, unless adequate construction is provided for these wells. People are inclined to seek water irrespective of its quality; quantity being the governing factor. An increase in water borne diseases, if not an epidemic, may then result. In many cases, there is an increased draft on the more reliable supplies, usually exceeding the capacity of the supply with a detrimental effect on the well. Failure by excess lowering or clogging of the sands or screen may, therefore, occur.

From the standpoint of sewage disposal, many difficulties are encountered. Cities and towns depending upon dilution as a means of final disposal for their sewage are confronted with serious nuisances. Along the streams that have lowered or dried, sludge banks can be found and in some cases difficulty is encountered in carrying the sewer to the main channel of the stream. Some of the present disposal plants are inadequate for treating of the wastes, as a more stable effluent must be provided than was necessary before the drought. The excess sewage loads on the streams complicate matters for those municipalities obtaining their water supplies from these sources and naturally creates a very undesirable condition for aquatic and fish life in the streams.

Available records indicate a possible further depletion in the ground water supplies. Having passed the driest months in the history of the State (since June, 1933) there is a demand that will not be satisfied with ordinary amounts of precipitation. Considerable moisture will be necessary to supply the demand of the upper layers of the soil, vegetation and evaporation, before any water from rain and snow will penetrate to the water bearing strata to add to the under ground storage.

Many suggestions have been made as to what to do with the situation. In some instances artificial means were resorted to to replenish some supplies. This was done by damming streams and flooding low areas. This solution, however, is only temporary. Some municipalities have reclaimed old wells by cleaning and others by drilling deeper. While the aforementioned methods have assisted considerably in relieving the drought situation the problem is by no means solved.

The drought, of course, has brought hardships upon many municipalities, but it has also emphasized the real value of a reliable water supply. It has provided a nucleus to a more systematic and comprehensive program for the development, maintenance and conservation of existing water supplies. Considerable information of real value may be collected from the effects of the drought, all of which should be sufficient as the basis for a definite program. There is much work to be done in locating accurately the existing aquifers, to determine their storage capacity, hydraulic behavior and safe yield. In sections where the ground water supply is limited, means should be provided to impound water in sufficient quantities to meet the ordinary needs in times of drought.

The Federal Government is constructing a large number of such reservoirs in the middle west at this time, and recent reports show that the relief administration of the State has contracted for the drilling of 78 new wells. These wells, of course, will be drilled on state lands with federal funds designed to combat the drought. Where existing supplies have withstood the drought, a careful study should be made to determine their safe yields and the possibilities of developing new supplies to meet any increase in demand without affecting the original source.

(Presented before the Missouri Valley Section meeting, November 9, 1934.)

THE EFFECT OF DROUGHT ON PUBLIC WATER SUPPLIES IN IOWA

By A. H. Wieters

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The State of Iowa may be roughly divided into three sections as to the predominating sources of water supply.

The municipalities in the southern third of the state, except in the extreme east where there are a number of deep well supplies and river supplies, and in the extreme west where shallow well supplies predominate, depend principally upon impounded surface water supplies.

The municipalities in the western fourth of the state and the west central portion of the state depend principally upon shallow wells, whereas in the remainder of the state the principal sources of municipal water supply are from deep wells.

Shallow wells are arbitrarily taken as those that are 100 feet or less in depth. For the most part the shallow wells terminate in the unconsolidated loess, glacial drift or alluvium, and the deep wells terminate in consolidated formations and may be classed as rock wells. There are, of course, exceptions as the result of the arbitrary depth classification. The drift is at least 200 feet deep in a few instances while in other cases wells terminate in bed rock at depths less than 100 feet.

The principal deep aquifers in the east part of the state are the St. Peter, Jordan, Dresbach and Mt. Simon sandstones and intermediate limestones and dolomites. These formations outcrop in northeastern Iowa, Minnesota and Wisconsin and dip to the southwest so that the St. Peter, the upper extensive sandstone, is about 3,000 feet below the ground surface at Greenfield in Adair County. These formations run roughly parallel to each other and are quite continuous although the thickness is not uniform.

As one progresses southwestward the yield becomes less, the depth greater, the distance from water to ground surface becomes greater and the water becomes heavily mineralized, with the result that in the southern part of the state the development of these waters is not promising.

The principal deep aquifer in northwest Iowa is the Dakota sandstone. The formation is non-continuous, yielding heavily in some localities and being entirely absent in others. For the most part water from the Dakota formation is heavily mineralized and therefore unsatisfactory.

The shallow waters in western Iowa occur mostly in loess, alluvium and glacial sands and gravels. The loess wells do not yield heavily, and lowering water table due to drainage and seasonal fluctuations in precipitation make this formation extremely unreliable for municipal supplies. Where extensive areas of gravel are found in preglacial and glacial stream beds, excellent yields are obtained. Where small local gravel pockets are tapped, however, the yields are very uncertain and fluctuate greatly with seasonal variations in precipitation.

The entire southern and western parts of the state are in the Kansan drift area. In some places the overlying loess yields small amounts of water, but usually the yields are insufficient for even small towns. Ordinarily it is only in the alluvium along the larger streams in the southwestern part of the state, and in underground preglacial or glacial stream beds, or alluvium along the streams in the northwestern part of the State that reliable yields can be obtained from the Kansan drift.

In the uplands in Kansan drift areas such as Dallas, Adair, Guthrie, Audubon and Cass counties, shallow wells have not been entirely successful from the standpoint of yields and great seasonal fluctuations in ground water table occur. In the south central portion of the state, extensive water-bearing gravel in the drift is almost entirely absent.

EFFECT OF DROUGHT

It is extremely difficult to secure reliable information on the effect of drought on the ground water table for few accurate records have been kept. Judging from observations made by the field engineers of the Department of Health, however, and from information furnished by questionnaires, the drought of the past two years has apparently had little or no effect on the deep aquifers. There are isolated instances of apparent lowering of the table of these aquifers where large quantities of water have been taken from comparatively small areas. However, such apparent lowering has been occurring over a period of years and does not seem to cover any extensive areas. It is more likely that the water is being taken from these fine sandstones

at a rate greater than the rate of travel through this material. The general conclusion must be that practically no effect on these aquifers is as yet apparent. It is possible that, due to the slow rate of travel of ground water through these sandstones, there might be a considerable lag in the effect of the drought and that lowering of the water table due to deficient rainfall of the past four or five years may occur during the next few years. On the other hand, the drought has not been as severe in the localities of outcrop of these formations as in other sections of the middle west and these outcrops are so extensive in area that the writer does not anticipate any serious effects.

In the shallow well area in the western part of the state there has been some apparent lowering of the ground water tables, although conditions reported are so non-uniform that a general conclusion cannot be reached. Local conditions, which are extremely variable, had a great effect on local situations. Fortunately, northwestern Iowa was not in the area of extreme drought and consequently the test on shallow ground water table was not as severe as in southern Iowa. Paradoxical as it may seem, in view of the extended drought, Sioux City experienced early in June, 1934, a near record flood following 7 inches of rain falling in this area during a 24-hour period.

According to information available, those shallow well supplies tapping underground glacial stream beds, stream underflows and gravel pockets of extensive area have not been seriously affected. Likewise those supplies tapping the alluvium adjacent to present streams have held up satisfactorily. On the other hand, those supplies tapping less extensive gravel pockets have shown appreciable lowering of ground water, in some instances as much as 20 feet.

In the extreme southwest corner of the state the shallow wells have shown some lowering, but there is no example of complete failure, in spite of the fact that stream flows reached the vanishing point in some instances and farm wells failed by the hundreds. Most of the public supplies in this part of the state tap gravel deposits in stream valleys, whereas farm wells tap local upland deposits with very limited storage or terminate in the loess above the drift. Previous droughts have shown the unreliability of the loess and local gravel deposits for municipal supplies and most of such supplies had been abandoned.

EXAMPLES OF WATER FAILURES

The most serious water shortages occurred among the artificially impounded surface water supplies in the southern part of the state.

Complete failures have occurred at Fairfield, Creston, Corning, Humeston, Lenox, Mt. Ayr and What Cheer, and supplies at Lamoni, Chariton and Tabor are quite low.

At Creston the most serious failure occurred. Creston, population 8,615, has a reservoir constructed in 1891 with an estimated storage of about 300 million gallons. The drainage area, 12,000 acres, is rather flat consisting of about 60 percent plow land and 40 percent pasture. The reservoir was last full in March, 1933. On May 3, 1934, the supply was depleted and an emergency pipe line was installed to a small recreational reservoir which also failed about a month later. From that time water has been shipped by tank car from Council Bluffs, a distance of about 75 miles, the E.R.A. assisting in the financing of the emergency supply. Fall rains have failed to replenish the supply.

The supply at Creston has been very low on several occasions previously, being almost depleted in 1930 when the fall rains came.

The cumulative deficiency of rainfall in August, 1934, was 22.61 inches as compared with 10.45 inches in 1931. Ratio of storage to annual consumption is 0.95. Added storage appears necessary.

Corning, population 2,026, has storage of 65 million gallons. The drainage area, 600 acres, is gently rolling land with about 50 percent plow land and 50 percent pasture. The reservoir was constructed in 1917. Date of last overflow was not recorded, but the reservoir was practically full in the spring of 1933. The cumulative deficiency of rainfall in August, 1934, was 23.57 inches compared with 8.22 inches in 1931. The supply failed on July 10, 1934, and water has been shipped in tank cars from Council Bluffs until the past week when local rains replenished the supply. Added storage is necessary and is easily available.

Fairfield, population 6,619, has three reservoirs with storage totaling 260 million gallons. Due to a drainage dispute and court injunction, water from Reservoir 3 was wasted and not available, leaving storage of about 180 million gallons. The drainage areas of the two reservoirs in use total 768 acres of about 70 percent pasture and 30 percent plow land. The date of last overflow from Reservoir 1 was 1933 and from 2 was 1928. The supply failed the latter part of August, 1934. Fortunately a deep well was available and this has supplied the community since that time. The cumulative deficiency in rainfall was 17.45 inches in August, 1934, as compared with 13.55 inches in 1930. Had the third existing reservoir been available no shortage would have been encountered to the present.

Lenox, population 1,717, has one reservoir of 18 and a second with 60 million gallons storage. Unfortunately early in 1934 the water from the larger reservoir was wasted to repair leaks in the earth dam and the town went into the summer with the large reservoir practically empty. The supply failed in October, 1934. The cumulative deficiency of rainfall was 13.71 in July, 1934, as against 8.24 inches in 1930. Water is being shipped in tank cars. The existing reservoirs should suffice if they are filled when possible.

Humeston, population 924, has one reservoir with a capacity of 45 million gallons and a drainage area of 650 acres. In spite of a relatively large storage factor as compared with other supplies which have failed, this supply failed in January, 1934. The cumulative deficiency of rainfall here was 21.88 inches in October, 1934, as against 12.22 inches in 1931. Shallow private wells have been used as source of water supply during the year. Added storage is required here.

What Cheer, population 1,310, ordinarily derives its supply from an impounding reservoir and a shallow well. The reservoir has a 4 million gallon capacity, with a drainage area of 900 acres. The reservoir supply failed in the summer of 1933 and the shallow well was used until mid-winter, when it failed. An abandoned mine was then tapped, but due to excessive mineralization the water is unfit for drinking and dependence has been placed upon cisterns and shallow private wells for drinking water. A deep test well is being constructed by E.R.A. and if this fails to produce an adequate quantity of satisfactory water, added storage is necessary. The storage reservoir has previously failed, but both the reservoir and well had not failed previously.

Osceola, population 2,871, has a small reservoir of about 10 million gallons capacity with a drainage area of 280 acres. The water is untreated and used only for flushing and fire purposes. Therefore the per capita consumption is extremely low. A new reservoir of 130 million gallons capacity and a drainage area of 2,500 acres, together with a modern treatment plant, was completed early in 1934. However, due to the drought no water has as yet been available from the new supply. Even with the low consumption, the old supply failed early in July, 1934, and water has been furnished from St. Joseph, Missouri, being pumped through an unused oil pipe line. Rainfall records are not available here.

Mt. Ayr, population 1,704, has a reservoir built in 1914 with a present capacity of 23 million gallons and a drainage area of 640 acres. The impounded supply proved insufficient in 1934, as in 1931.

However, in 1931 a nearby creek was dammed and water pumped to the reservoir. With curtailment of water consumption the supply has not completely failed, but added storage is necessary.

Tabor, population 1,048, has a small reservoir impounding 4.5 million gallons with a drainage area of 770 acres. This reservoir is spring fed and had proven ample until 1934. Curtailment of the use of water has been necessary since July, 1934, and the springs have been cleaned out and water pumped to the reservoir. The town has been able to get by with difficulty. Recent rains filled the reservoir.

Impounded surface supplies which have held up in the area are those at Albia, Chariton, Corydon, Centerville and Lamoni.

Unfortunately there are no run-off records available in this part of the state and information on pertinent data such as decrease in reservoir capacities due to silting, evaporation and leakage through and under dams, is very meager. Consequently any conclusions must be based upon general observations rather than upon theoretical considerations.

Pertinent data on some of the impounded supplies in the southern part of the state are shown in table 1.

These data reveal strikingly that inadequacy of drainage area had little or nothing to do with water failures during the present drought, in that most of the failures have occurred in places with the largest drainage areas. For example, at Creston with an annual consumption of but 0.025 million gallons per acre drainage area the supply failed in May, 1934, whereas at Centerville with an annual consumption four times greater per acre of drainage area the supply has been entirely adequate.

The figures on storage indicate definitely that the failures must, for the most part, be attributed to insufficient storage. Whereas at Creston the ratio of storage to annual consumption is but 0.95, at Albia the ratio is 3.24. Likewise the ratios of consumption to annual storage are appreciably higher in all places where the supplies have proven sufficient as against those places where failures have occurred.

During the summer of 1934, evaporation no doubt reached excessive figures as compared with normal years. Unfortunately no figures are available for the area under discussion, but at Ames, which was also in the drought area, experiments indicated that evaporation proceeded at a rate very much higher than was considered normal for the area. No doubt excessive evaporation played a large part in failure of water supplies, and evaporation losses are probably the greatest single factor in estimating storage needs. Yet the ratios of

TABLE 1

Data on impounded water supplies in Iowa

CITY OR TOWN	POPULATION 1930	PUMPAGE, M.G. PER YEAR	DRAINAGE AREA, ACRES	WATER SURFACE, ACRES (FULL)	STORAGE, M.G. (FULL)	M.G. STORAGE / ACRES W.S. (6) ÷ (5)	POPULATION / M.G. STORAGE (2) ÷ (6)	CONSUMPTION / ACRES D.A. (3) ÷ (4)	M.G. STORAGE / CONSUMPTION (6) ÷ (3)	CHARACTER DRAINAGE AREA	M.G. 9–15–34	DATE CONSTRUCTED	DATE PREVIOUS FAILURE	DATE LAST OVERFLOW	AVERAGE DEPTH	REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Albia	4,425	105	805	50	370	7.4	12.0	0.13	3.24	Steep pasture	225	1924		Oct. 1931	4.5	
Centerville	8,147	185	1,700	187	400	2.1	20.4	0.11	2.17	Rolling wooded pasture and plow land	150	1922		Sept. 1933	10 42 31	
Corydon	1,768	28	1,920	38	70	1.9	25.2	0.02	2.5	Gently rolling, 75% pasture, 25% plow land	60	1917		Fall 1932	6	
Fairfield	6,619	135	768	58	180	3.1	36.7	0.17	1.33	Rolling, 55% pasture, 45% plow land	Failure 8–34	1900		No. 1, 1933 No. 2, 1928	10 10 5	Additional storage constructed but not available due to legal litigation
Lamoni	1,739	15	400	30	30	1.0	59.9	0.04	2.0	Gently rolling, 50% pasture, 50% plow land	*	1908	1926	*	15	Part of supply from deep well
Corning	2,026	37	600	12	65	5.4	31.1	0.06	1.75	Rolling, 50% pasture, 50% plow land	Failure 7–34	1917		*		
Creston	8,615	310	12,000	175	296	1.7	34.4	0.03	0.95	Flat, 60% plow land, 40% pasture	Failure 5–34	1891		Mar. 1933	12	
Humeston	924	22	650	23.6	45	1.3	20.5	0.03	2.05	Rolling, 75% pasture, 25% plow land	Failure 1–34	1914	1926, 1931	Apr. 1932	6	
Lenox	1,717	17	90	7.5	18	2.4	95.3	0.19	1.06	Pasture	Failure 10–34	1923		Mar. 1933	14	Large reservoir emptied Spring, 1934, for repair
Chariton	5,365	137	960	65	300	4.6	17.9	0.143	2.19	Pasture and plow land	40	*		Spring 1930	16	New reservoir under construction

* No information.

storage to water surface do not appear to be deciding factors in the failures of 1934.

RAINFALL DEFICIENCIES

Local rainfall also played an important part, which cannot be evaluated due to the lack of run-off data. For instance, at Corydon where crop failure was almost complete the water reservoir showed no abnormal lowering during the summer due to a few intense rains. As against this, Creston enjoyed rainfall above normal for September, 1934, yet there was no appreciable run-off from this exceptionally large drainage area.

That the rainfall was far below normal for the past eighteen months is evidenced by the figures showing the cumulative departures from normal rainfall. The cumulative deficit for 1933–1934 as compared with the cumulative deficit for the drought period 1930–1931 when there were no complete failures, is striking. For some of the communities under observation the cumulative deficiencies for the 1933–1934 periods were almost three times those of the earlier drought period.

One river supply, namely, Bedford, failed completely. Only a low dam is provided here, affording negligible storage. The supply also failed in the fall of 1930. Other river supplies proved adequate, although at Des Moines during the latter part of August, almost the entire flow of the Raccon River was pumped to the lagoons which replenish the underground water that is collected by the infiltration galleries.

SUMMARY

While scientific data upon which accurate predictions may be based are lacking, the experience of the past year has pointed out several lessons.

It has shown that in southern Iowa storage equal to the consumption, evaporation and percolation for periods of more than a year is necessary unless auxiliary supplies of ground water are available.

It has shown the need of obtaining information on run-off, evaporation, percolation and of keeping records of silting of reservoirs and seasonal fluctuations in water levels of the reservoirs.

It has shown the need of determining the location of underground glacial or preglacial stream beds which furnish adequate water in western and northwestern Iowa.

It has shown the need of keeping records of fluctuations in water level in existing wells so that some conclusions can be reached as to the general lowering of the ground water table.

Fortunately the situation in Iowa is readily amenable to practical solution. Iowa is ordinarily a well watered state and it only remains to adequately develop and conserve the natural water resources. In two-thirds of the state no serious problem exists. In the northwestern part of the state the Dakota sandstone water is available in many places and it is believed that sufficiently extensive underground gravel formations can be located, although in many instances, due to the distance of such formations from existing communities, the cost of development will be more than Iowa municipalities are accustomed to spend.

In the southern part of the state the land is rolling and innumerable excellent reservoir sites for impounding surface water are available. Here again the cost of development is high for a small municipality. However, one of the lessons learned because of the drought is that cost is a secondary consideration where failure of a water supply is imminent.

The State E.R.A. under the Drought Relief Program is engaged in assisting several municipalities in deep well drilling programs in the southern part of the state. It is felt by reliable geologists that some of the upper deep aquifers in the southern part of the state have not been thoroughly tested as to yield and mineral content and several test wells are being drilled. Each horizon will be tested, both for quantity and quality, as it is encountered. Past experience in the few deep wells in southern Iowa has not been promising in view of the low yields, the high mineralization and the excessive lifts. However, in all existing deep wells in this area several horizons have been penetrated and no particular effort has been made to determine which of the aquifers may be responsible for the heavy mineralization. These tests, as they are being conducted, should definitely settle the question as to whether or not deep well waters for domestic purposes are available in southern Iowa. If such test wells fail to provide adequate yields of satisfactory water, they still will be available for emergencies such as the one through which we are now passing.

The Iowa State Planning Board in coöperation with the E.R.A., the State Geological Survey and the State Department of Health, is

now engaged in an extensive study of water resources of the state and plans for the best utilization of such water resources. It is hoped that these studies will result in a public works program which will prevent a recurrence of the unfortunate situation which existed in southern Iowa in the summer of 1934.

(Presented before the Missouri Valley Section meeting, November 9, 1934.)

PUBLIC AND EMERGENCY WATER SUPPLIES DURING THE DROUGHT PERIOD IN KANSAS

By Earnest Boyce

(*Chief Engineer, State Board of Health, Lawrence, Kansas*)

The occurrence of critical water shortages during a period of rainfall deficiency is dependent both on the nature of the water usage and upon the capacity of the available natural and constructed storages to equalize the irregularity of the supply with the more continuous demand.

Except in irrigated areas, the minimum water requirement for growing crops is provided by the replenishment of the moisture content of the soil by rainfall. A deficiency in rainfall is quickly reflected by a drought effect upon growing crops, with the degree of crop failure depending on the length and severity of the water shortage, its relation to the growing season, and the character of the soil.

While water shortages may diminish the yield or cause the failure of certain crops, the frequency of occurrence of water shortages that would affect growing crops has had a controlling effect on the areas developed for agricultural use.

For all use other than growing of unirrigated crops, we must consider some method of storage to supply the water requirements between rains. There is no better or cheaper storage than that provided by porous geological formations. These formations, if near the surface readily absorb rainfall and hold it underground, slowly releasing it during dry periods to furnish the source of ground water supplies and the dry weather flow of streams. When these natural water storage formations as developed by wells, fail to furnish a supply of water adequate to meet the water usage demand, certain problems present themselves for study and engineering investigation.

The first problem is to determine the character and extent of all possible water-bearing formations and to determine whether or not existing water supply structures are capable of exhausting all of the available supply.

The second problem has to do with the curtailment of water usage

in order that the available water resources may be conserved for their most important purposes.

The third has to do with an analysis of the water storage situation and a study of the possible methods of increasing this storage to make it adequate for future water usage needs.

While the first and second problems are more definitely related to the present water shortage situation, the question of future water shortages resolves itself into an analysis of the problem of providing for an increase of water shortage in an amount that will adequately supplement natural storages.

It will be the purpose of this paper to discuss briefly the geological and climatological factors that will require careful analysis in the development of any long-time program of water conservation and to conclude with a narrative review of the program for giving immediate relief from acute water shortage.

GEOLOGICAL FACTORS

Kansas soil regions outline areas that vary widely in their capacity to provide water storage. Northwestern Kansas is covered with wind deposits that overlie residual soils of the Tertiary period. The coarse granular nature of the western residual soils reflect their granitic origin and because of their extent and high water yield are important aquifers. They overlie shale beds of irregular conformation whose depressions collect the water and make it available for well development.

The alluvial deposits of the Arkansas and Kansas river valleys cover large areas and make an important contribution to the underground water resources of the state. Northeastern Kansas geology is influenced by extensive glacial deposits. These formations are fairly compact in those areas unmodified by subsequent erosion and water classification of the eroded material. Fortunately from a water resources standpoint small alluvial deposits have been formed and local aquifers exist to furnish many municipal supplies.

The residual soils that result from shale disintegration are fine-grained and have a very limited water yield. The soils of the southeastern section of Kansas are formed from lime, sandstone and shale residuals. Except for local sandstone areas and limited alluvial deposits the geological structure is generally unsatisfactory from the standpoint of underground water resources. Municipal supplies are obtained from impounding reservoirs or from rivers and river-channel

storage. Fortunately most Kansas drainage areas extend from west to east and bring a dry weather flow from regions of good water storage formations to areas dependent on surface water supply.

RAINFALL RECORDS

Kansas rainfall records show an average annual rainfall of from an amount in excess of 40 inches per year in the southeast section of the state and 35 inches in the northeast section, to less than 20 inches in the western counties. With a high annual rainfall and a generally impervious soil it is possible to provide surface storage to meet all municipal and industrial requirements of the southeastern section. Rural water supplies are obtained from small-capacity wells and storage cisterns with farm ponds as an important source of supply for stock water.

PROVISIONS FOR STORAGE

Water storages for drought periods in this section of the state may be expected to take the form of well designed and adequate farm ponds for rural stock water supply and an increase in the number and capacity of impounded supplies for municipal and industrial use. Overflow dams in the principal streams may be proposed as a means of increasing channel storage. Such storages are desirable not only from the standpoint of water supply quantity, but also from the standpoint of quality. An increased time of flow would result from an increased channel storage, thus providing additional opportunity for biological stabilization of the used water discharged from the sewage treatment plants up stream.

Consideration is being given to the possibility of providing large storage dams at the headwaters of some of these streams, not only for the primary purpose of retarding flood flow, but also for the purpose of providing an increased minimum stream flow.

For example, it is being proposed that a storage be provided for 45,000 acre feet on the headwaters of the Neosho River. This amount of storage would be sufficient to provide a continuous discharge of 100 cubic feet per second for 220 days and would have value not only from the standpoint of additional supply for the municipalities dependent on that stream, but it would also provide a volume of water for the dilution of industrial wastes of mineral natute that are produced on the tributary area.

In addition to the study of surface storage as a means of providing

water supply and increasing stream flow, a water conservation program should properly devote considerable time to the development of a plan that will insure the replenishment of underground water storages.

In the development of a plan for the more complete utilization of the excellent water producing formations of western Kansas, it is essential that careful geological explorations be completed and the important storage formations located. The retardation of surface runoff by terracing and by the construction of small farm ponds has been started as a part of an emergency water supply and soil conservation program. It is possible that this program if extended may result in a definite increase in the percolation ratio in those areas where good water storage formations exist.

In western states where underground water storage forms an important part of the irrigation supply, definite works have been constructed for the purpose of spreading runoff water over water storage formations. Due to the high evaporation rate in western Kansas it is especially important that subsurface rather than surface storage be developed as fully as is possible.

It is quite possible that the careful analysis of the whole problem of water storage and utilization that is resulting from the drought through which we are passing may ultimately lead to a plan for a more complete development of this important natural resource.

During the past several months Kansas has engaged in an active governmental program to minimize drought effect. From what has just been said it will follow that such a program could not result in the maximum relief from the effect of deficient rainfall due to a failure to plan during a period of normal rainfall for the storages that would have been of value during the drought.

EMERGENCY WATER CONSERVATION PROGRAM

The emergency water conservation program started with the action of Governor Landon in securing the loan of several hundred pumping units, both gas and motor driven from oil producing companies to be used to pump from rivers, creeks, and ponds into storage tanks placed on the bank from which farmers and stockmen could haul water for livestock.

This action was followed on July 19 by the announcement of a water conservation program as a part of the Drought Relief Service of the Kansas Emergency Relief Committee, the state organization

of the Federal Emergency Relief Administration. The purpose of this program was outlined by the executive director, John G. Stutz, in his bulletin announcing its organization as follows:

The Water Conservation Program, as a part of the Drought Relief Service, is designed to aid in relieving destitution actually resulting from drought conditions; that is, need for relief which has been caused by the drought, either new need or increased need.

The Water Conservation Program is intended to afford wells, ponds, lakes, dams, canals and other devices which will conserve water in Kansas for agricultural and industrial purposes and for all other human needs.

The program will begin at once. All work must be such as can be completed by March 1, 1935.

For purposes of analysis, the program will be considered under the following heads.

1. Wells for domestic use.
2. Garden ponds and farm ponds.
3. State, county and city lakes.
4. Soil erosion.
5. Municipal water supplies.

The citizens and public officials of a county are expected and requested to take up all their questions or requests with the County Poor Commissioner, who is the administrative head of the County Relief administration. The County Poor Commissioner, or one of his authorized assistants, will contact the state supervisor or the state office of the Kansas Emergency Relief Committee for any information or service which the county relief administration needs in the conduct of its business and the meeting of its responsibilities.

In a later bulletin of the State Relief Administration the Director expressed certain principles and policies that would govern the operation of the water conservation program as follows:

The Kansas Emergency Relief Committee has put into operation what it believes is a comprehensive far-sighted program, designed not only to take care of the present water shortage, but to build and to conserve for the future. This program, which has been designated by the Federal Emergency Relief Administration as a drought relief measure, nevertheless will result in permanent benefit to the state. The Kansas Emergency Relief Committee, as the administrative agency for the operation of this program, is insisting upon the maintenance of proper engineering standards in the construction of wells, ponds and lakes, so that both individuals and the state as a whole will obtain the maximum advantage from the expenditure of federal funds.

The money for water conservation has been granted the Kansas Emergency Relief Committee only upon the condition that it complies with certain fundamental regulations, among them:

1. No funds shall be used for the purchase of lake or pond sites.
2. Only 25 percent of federal funds can be used for materials.

3. For farmers not on relief, allotment only of engineering and supervisory services and some available materials not on farm.
4. Approval of projects which can be finished by March 1, 1935.

All projects must receive final approval from the engineering department of the Federal Emergency Relief Administration. If these regulations are not complied with in Kansas, funds will not be available for water conservation.

Splendid coöperation has been secured from such existing state agencies as the State Board of Health, the State Board of Agriculture and its Division of Water Resources, the State Geological Survey, Extension Division of Kansas State College at Manhattan and many individuals who have been supplying the Kansas Emergency Relief Committee with needed data. The information supplied to the Kansas Emergency Relief Committee is of specific value and being welded into a comprehensive whole it will be made available to the state at large.

The program as outlined and carried out during the subsequent months made provision for the construction of wells for domestic use, garden and farm ponds, state, county and city lakes and soil erosion projects to prevent silting of surface storages. The prescribed procedure outlined in the program is given in a K. E. R. C. bulletin dated August 27, 1934 as follows:

Wells

"Where water shortage for human and livestock needs exists owing to conditions produced by the drought, either on privately or municipally owned property, we will undertake to give aid in locating suitable water supplies through the services of geologists. Work relief labor may be used in putting down the tests. Wherever the owner as a private citizen or as a municipality is unable to finance the digging or drilling of the well at the owner's expense and if the supply, where privately owned, is needed by the community, the county relief administration will be authorized to use a limited amount of available federal emergency relief funds or funds which we will undertake to make available on proper request, with which to drill or dig the well, and provide suitable well casing. In most instances, farmers will be able to transfer their present pumping equipment from the old wells to the new ones. In instances where this cannot be accomplished, the local relief administration will be authorized to rent suitable pumping equipment and to operate same out of their grant of material funds and with work relief labor. The material funds may be used not only for casings for the wells, but for making the well platform and for the construction of necessary scaffolding for a suitable stor-

age tank. The storage tank may be included in the equipment rented.

The land owners on whose farms wells are built with the aid of federal emergency relief funds will give easement to the county which will provide that whenever the Board of County Commissioners, by resolution, declares that an emergency exists for water supply, the owner of the land on which the well is situated will allow his neighbors and other citizens of the county access to the well for emergency water supplies. A form of easement will be supplied by the Kansas Emergency Relief Committee."

Garden ponds and farm ponds

"The garden pond is defined as one constructed near a windmill or pump which supplies water for the pond, the pond being used as a reservoir for irrigation of gardens, trees and in some cases as a reservoir for stock. (Applicable only in certain areas.)

Farm ponds (designated by the state statutes as water reservoirs on dry water courses) are those located in the water shed on the farm and are used to conserve water for wells further down the water shed, for stock water and in some cases for the irrigation of gardens and trees.

Each pond must be fenced to keep livestock from the pond, dam, and trees planted in the area below the dam.

Trees, furnished by the Kansas Emergency Relief Committee or trees approved by it, must be planted below the dam, the kind of trees, location and general scheme of planting to be designated by the landscape architect of the Kansas Emergency Relief Committee. This area below the dam should not average more than one-half acre.

The owner or owners of the land upon which farm ponds are built with federal emergency relief funds will give easement to the county which will provide that whenever the Board of Commissioners, by resolution, declares that an emergency exists for water supply, the owner of the land on which the pond is situated will allow his neighbors or other citizens of the county access to the pond for emergency water supplies. The form of the easement will be supplied by the Kansas Emergency Relief Committee.

The necessary engineering and supervision of construction will be furnished on all garden ponds and farm ponds. Where power equipment and teams and/or work relief labor is available, certain piece work or a percentage of the work of construction of each farm pond in the county, approved under a given application or project number,

may be provided with the approval of the Kansas Emergency Relief Committee.

The state laws provide that whenever a farmer constructs a farm pond called a water reservoir in a dry water course, according to the specifications by the State Engineer of Water Resources such farmer will be given credit on his farm assessed valuation to the extent of $40.00 for each acre-foot. The farmer must maintain such ponds in good condition and in accordance with the specifications in order to be eligible for this credit.

The minimum farm pond size to be included in this program shall be a surface area of not less than one acre at the elevation of the spillway, and the maximum farm pond size shall not exceed fifteen acres at the elevation of the spillway."

State, county and city lakes

"Lakes will be constructed or reconstructed in so far as funds are available. Lakes will be constructed only on land owned or held under lease or easement deeds by the State of Kansas or one of its political subdivisions authorized to own and maintain a lake. The lease or easement must be for 99 years or so long as the lakes shall be maintained. Lakes will be considered for construction, provided there are funds available, where there is a suitable supply of work relief labor, a suitable water conservation site, project economical to build and maintain, a project with recreations or municipal water supply resources.

The Kansas Emergency Relief Committee will give preliminary consideration to city, state, or county lake projects when submitted by such city, state, or county, who is the owner or proposed public owner, when such preliminary projects show that:

1. The public owner, or proposed public owner, has done sufficient preliminary engineering work to satisfy itself that the project would be feasible and acceptable to it.
2. The public body now owns or has an assurance that it will be able to furnish the site either as owned or properly leased.
3. The proposed project is a sound water conservation project.
4. It will be economical to build and maintain.
5. It has recreational resources.
6. A certificate from the county relief administration that there is or will be available work relief labor with which to complete the project within the limits provided in these regulations.

Whenever the governing body of a city, the board of county commissioners, or the State Fish and Game Commission have a proposed

project meeting the foregoing preliminary requirements, we will undertake to give it prompt consideration."

River dams

"The low-water or overflow type of dam may well become a part of this program. This should be located on running streams with relatively deep channels and where proper easements for emergency water supply and public fishing and hunting can be obtained from the land owners. Suggestions relative to this class of sites also will be given every possible consideration.

Public owners or public bodies holding proper leases or easements to such proposed sites containing the following essentials may submit preliminary projects:

1. Relatively small dam structure.
2. Stable river banks at the dam sites.
3. Fall of river not exceeding approximately six feet per mile.
4. Proper easements obtainable from the owners of the abuting property.
5. Reasonably accessible to the public highway."

Soil erosion

"To prevent the silting of ponds and lakes, which so frequently occurs where cultivated areas form a considerable portion of the watershed, erosion control measures will be included in each lake and pond project. The erosion control program will include terracing, vegetative coverings, and corrective cultural practices. The control of soil erosion will be under the supervision of the Kansas State College Extension Service and its county field workers.

Terrace work and its financing will be handled in the same manner as for the farm ponds and lakes.

The necessary engineering and supervision will be furnished on all terracing required under this program."

Municipal water supplies

"The Water Conservation Program of the Kansas Emergency Relief Committee includes provisions for aiding cities, through work relief projects to strengthen their water resources where they are now being affected by the drought; that is, if a city has a shortage of water, or needs an additional well, some additional pipe laid, the ground water supply reservoir increased in capacity, or a drainage area improved, it can make a work relief project for any of those purposes."

The program noted above from the instruction circulars of the State Emergency Relief organization is now in progress. Much assistance has been given local communities in the location of emergency well water supplies with the aid of trained geologists and engineers employed by the Relief Administration. In some cases unsuspected sources of ground water have been found. In other instances, a knowledge of ground water geology has made it possible to so locate wells as to secure a maximum yield from known water formations.

Farm ponds have been located and constructed with due regard to runoff and storage capacity. The application of simple engineering and geological principles by technically trained personnel should produce an educational effect that will result in a better comprehension of some of the problems of water conservation.

OTHER PROGRAMS

In addition to the emergency program of the Kansas Relief Committee developed to offset in so far as possible the immediate effect of the drought, special mention should be made of the program of the State Forestry Fish and Game Commission. During the past several years one of the principal objectives of this Commission has been the stimulation of a public interest in the construction of state lakes for park purposes. Their educational and construction program has done much to create interest in the possibility of increasing the recreational facilities of the state, especially with regard to the possibility of large surface water storages.

In general, the municipal water supplies of Kansas were not seriously affected by the water shortage. While there are outstanding exceptions, these shortages had been for the most part previously anticipated by the city's water department.

The program of the Public Works Administration and the Civil Works Administration centered public attention on inadequate public water supplies with the result that a well balanced construction program was adding reserve capacity to municipal supplies early enough to be of aid in the drouth emergency.

As the emergency developed this construction program was supplemented by work undertaken as a part of the program of water conservation under the Relief organization.

(Presented before the Missouri Valley Section meeting, November 9, 1934.)

AN ANALYSIS OF UNUSUAL PRECIPITATION RECORDS IN IOWA

BY F. T. MAVIS, *Associate Director in Charge of Laboratory, Iowa Institute of Hydraulic Research, and Acting Head of Department of Mechanics and Hydraulics*

AND

J. W. HOWE, *Assistant Professor of Mechanics and Hydraulics, The State University of Iowa, Iowa City, Ia.*

Iowa has just experienced a twelve-month period of drouth which was apparently more severe than any calendar year of record. It is rather natural for us just now to overlook the fact that of the 47 most severe storms which have occurred in the northern section of the United States—as reported in studies of the Miami Conservancy District—ten have covered greater or lesser areas in the state of Iowa. This means that Iowa has had more than her share of intense rainstorms and evidently most of us are ready to agree that the state has had at least her share of dry years.

With the view to presenting a perspective of certain usual and unusual Iowa precipitation records not too severely warped by the recent dry years of 1930 and 1934, we have attempted herein to review briefly some of the unusual experiences recorded in the climatological summaries of the Weather Bureau.

This paper deals with monthly and annual precipitation records only. The study is divided into two parts: (1) a recital of certain past experience in annual precipitation, and (2), an analysis of usual and unusual monthly precipitation records in various sections of the State.

Isohyetal maps have been prepared showing (1) the arithmetic mean annual precipitation based on the total accumulated record at each of the rainfall stations within the state, (2) the rainfall distribution in the year 1881 which was the wettest year of record for the state as a whole, (3) the rainfall distribution for the year 1910 which was the driest calendar year of record in the state, and (4) the rainfall distribution for a twelve-month period ending May 31, 1934. The last period, of course, is the one which is still uppermost in our minds.

Charts and tables have been prepared showing a résumé of an analysis of usual and unusual precipitation records by months for various sections of the state. The analysis is a feeble attempt to throw light upon the following question: On the basis of climatological records how have wet months, dry months, and normal months combined to make up the wettest years, driest years, and mean years at selected stations within the State? Although there appeared to be a certain uniformity in the results obtained this significant question is by no means answered.

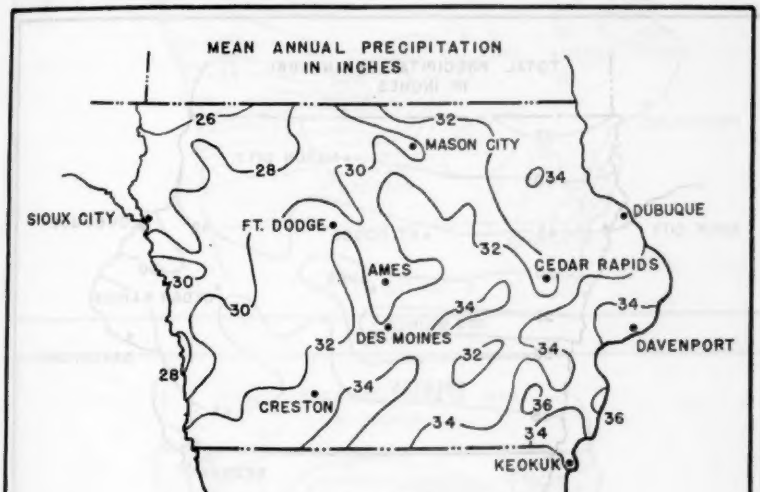

FIGURE 1

RÉSUMÉ OF STATEWIDE ANNUAL MEANS AND EXTREMES

Considering the state as a whole, the arithmetic mean annual precipitation is about 32 inches. The arithmetic mean annual precipitation at individual stations varies from about 26 inches in the extreme northwest portion of the state to approximately 36 inches in the extreme southeast portion. Figure 1 shows the isohyetals or contours of mean annual precipitation as determined from the records at more than 100 stations maintained by the Weather Bureau. While these isohyetals are roughly normal to the general slope of the state, which is downward from northwest to southeast, one should by no means infer that there is any relation between the variation of mean annual precipitation and general slope of the ground surface.

The year 1881 is the wettest calendar year on record in Iowa. The precipitation throughout the state that year would have covered it to an average depth of 44.2 inches. There were relatively few rainfall stations in operation in the state in 1881 and the contours in figure 2 showing the distribution of precipitation in that year may only approximate the distribution which actually occurred. The greatest amount of rain fell in a belt extending westward from Des Moines to the Missouri River. In this area, and in a small area near Dubuque, the total rainfall for the year exceeded 55 inches.

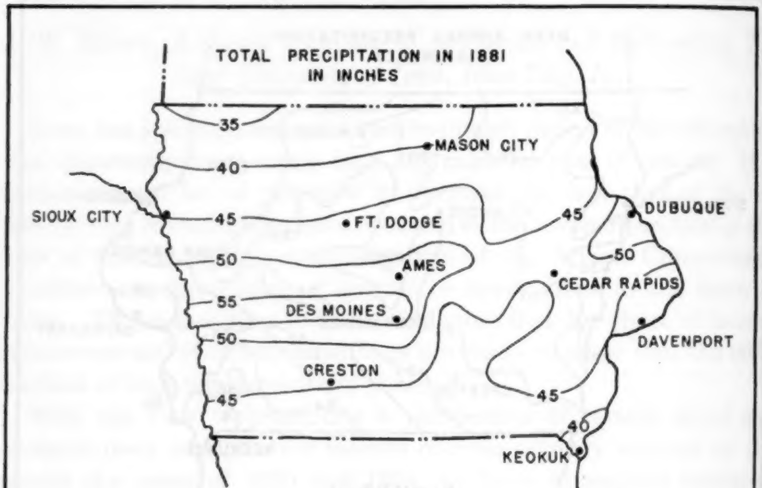

FIGURE 2

Figure 3 shows the amounts of precipitation which fell in 1881 in excess of the arithmetic mean precipitation at the corresponding station. The contours of figure 3, which were determined from figures 1 and 2, indicate that the annual precipitation in the western part of the state exceeded the mean there by a maximum of about 26 inches. Near Dubuque the year's precipitation exceeded the average by about 20 inches. In the northern tier of counties, the precipitation in 1881 exceeded the mean 8 to 10 inches and in the extreme southeast portion the excess was approximately 4 inches.

The year 1910 is the driest calendar year on record in Iowa. During that year the total precipitation which occurred would have covered the state to an average depth of 19.9 inches. Figure 4,

showing the distribution for the year, indicates that there were six relatively small zones in which the rainfall reached a maximum value

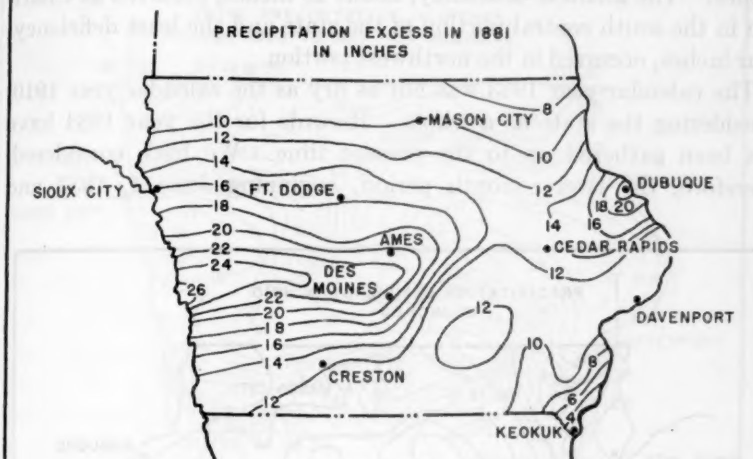

FIGURE 3

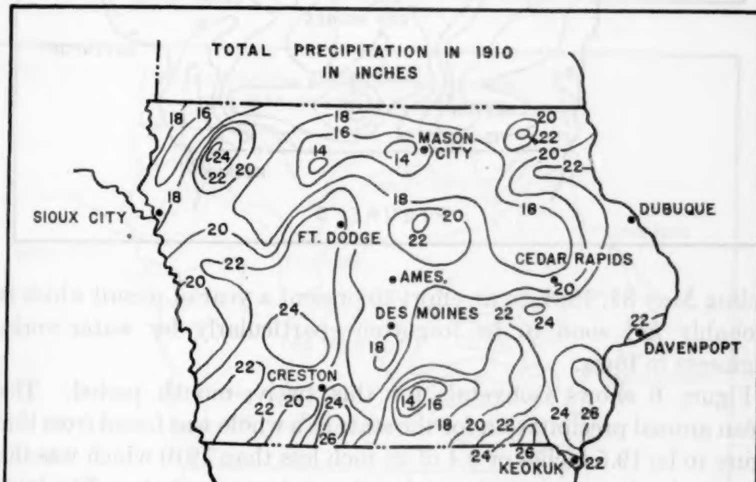

FIGURE 4

of 24 to 26 inches and there were three zones in which the rainfall for the year was less than 14 inches.

Figure 5 shows the deficiency of precipitation for the year 1910 referred to the individual station averages for all the years of record. The mean deficiency that year for the state as a whole was about 12 inches. The greatest deficiency, about 20 inches, occurred at Chariton in the south central portion of the state and the least deficiency, four inches, occurred in the northwest portion.

The calendar year 1933 was not as dry as the calendar year 1910, considering the state as a whole. Records for the year 1934 have not been gathered up to the present time. We have considered, therefore, the twelve-month period, beginning June 1, 1933 and

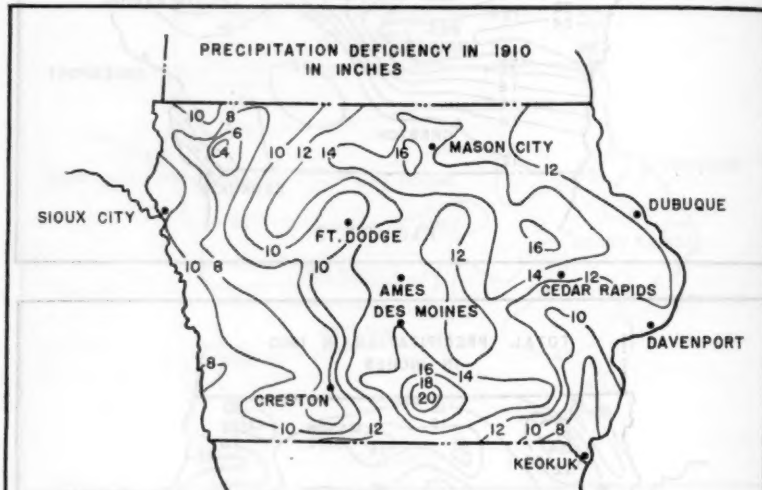

FIGURE 5

ending May 31, 1934, in an effort to present a year of record which is probably not soon to be forgotten—particularly by water works engineers in Iowa.

Figure 6 shows isohyetals for this twelve-month period. The mean annual precipitation for the state as a whole was found from this figure to be 19.5 inches or 0.4 of an inch less than 1910 which was the driest calendar year on record for the state as a whole. The least total amount of precipitation occurred at Williamsburg and amounted to 13 inches.

Figure 7 shows the total deficiency of precipitation for this twelve-month period referred to the mean annual precipitation at correspond-

ing stations. The greatest deficiency, occurring near Williamsburg, exceeded 20 inches. The southern part of the state suffered a fairly

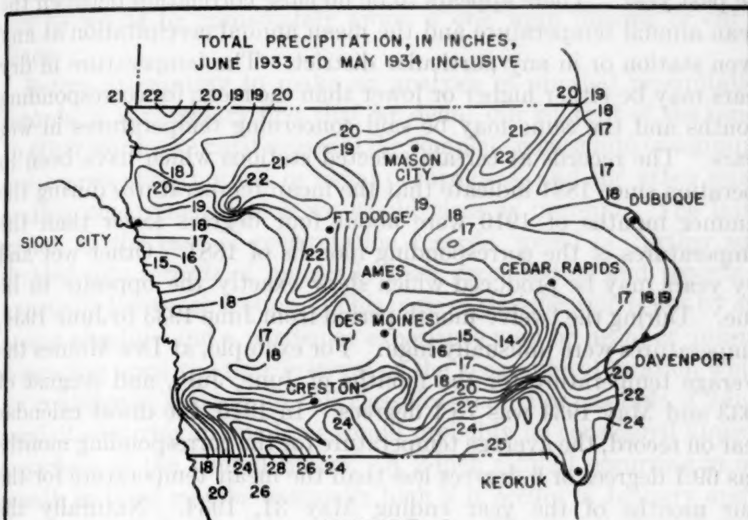

FIGURE 6

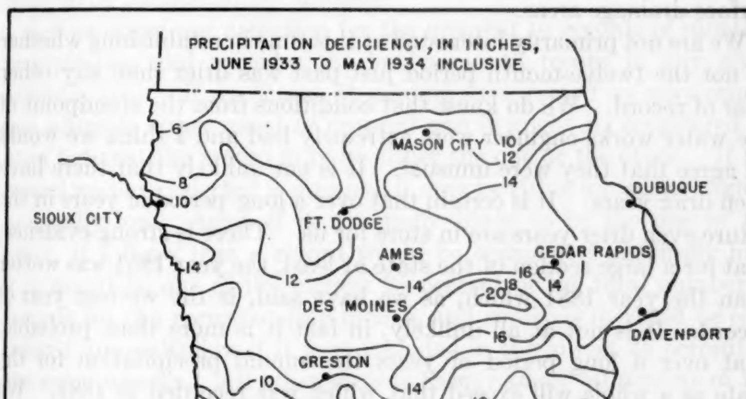

FIGURE 7

uniform deficiency of ten to 14 inches during the same twelve-month period.

There is one other factor, namely temperature, which cannot be overlooked in considering the unusually low precipitation records of the past year. There appears to be no close correlation between the mean annual temperature and the mean annual precipitation at any given station or in any particular district. The temperature in dry years may be either higher or lower than the mean for corresponding months and the same may be said concerning temperatures in wet years. The records at certain selected stations which have been in operation since 1881 indicate that the mean temperatures during the summer months of 1910 were about four degrees lower than the temperatures of the corresponding months of 1881. Other wet and dry years may be produced which show exactly the opposite to be true. During the twelve-month period from June 1933 to June 1934, temperatures were unusually high. For example, at Des Moines the average temperature for the months of June, July, and August of 1933 and May 1934 was 75.1 degrees. In 1910, the driest calendar year on record, the average temperature for the corresponding months was 69.1 degrees or 6 degrees less than the mean temperature for the four months of the year ending May 31, 1934. Naturally the evaporation from reservoirs which may have existed during the past year was high and other factors conspired to reduce the yield of surface drainage areas.

We are not primarily interested at this time in establishing whether or not the twelve-month period just past was drier than any other year of record. We do know that conditions from the standpoint of the water works engineer were extremely bad and I think we would all agree that they were unusual. It is not unlikely that there have been drier years. It is certain that over a long period of years in the future even drier years are in store for us. There is strong evidence, that for a large section of the state at least, the year 1851 was wetter than the year 1881 which, as we have said, is the wettest year of record. It is not at all unlikely, in fact it is more than probable, that over a long period of years the annual precipitation for the state as a whole will exceed that which was recorded in 1881. We have reason to hope after our experience of the past few years that we will, for a time at least, have years of rainfall more within the range of normal rainfalls for the state of Iowa.

ANALYSIS OF UNUSUAL PRECIPITATION RECORDS

In general we pay relatively little attention to things which usually go on about us. We accept the ordinary and are often not conscious

that a thing is ordinary until our attention is directed to it by the occurrence of something out of the ordinary. The average man, for example, might be unable to tell how many buttons were on his vest, but he would be immediately aware if one were missing or out of place.

Before attempting to make an analysis of unusual precipitation records, it is necessary first that we define our concept of the usual. In other words, we must separate the complete record into two groups, one representing normal or usual occurrences, and the other representing occurrences which we would class as unusual. The latter group, in the case of precipitation records, would be further subdivided into records of unusually high precipitation and records of unusually low precipitation. This basis of classification is not by any means absolute and a particular experience may be usual or unusual depending upon the time interval or the geographical location which we consider in making up this classification. For example, a 2-inch rainfall occurring in one hour would probably be considered unusual anywhere in the United States. A 2-inch rainfall occurring in one month in Iowa may be unusually high if it occurs in January and it may be unusually low if it occurs in June. There are in Iowa several months during the year in which a monthly rainfall of 2 inches would have to be considered not unusual.

Let us direct our attention for the moment to records of monthly precipitation and consider the twelve-month record in any given calendar year. If we choose at random some record we may choose one which is either usual or unusual and it might be considered an even bet that the record may be either the one or the other. If the record we have selected is unusual, it may be either unusually high or unusually low. Again if it is equally likely to be the one or the other, it follows that a record would be considered unusually high if it would be one of the highest 25 percent of the total number of records for the corresponding month, and similarly it would be considered unusually low if it were included in the lowest 25 percent of the same records. All other records then, namely 50 percent of the total number which lie between the unusual records would therefore be considered not unusual or normal.[1] The normal precipitation in this sense is not defined by a single value, but rather it is defined by a belt or zone which is included between two values so selected that it

[1] The term normal in this sense is evidently not the same as the modal value of the statistician or the arithmetic mean value which is often reported in climatological records.

is an even bet that any record selected at random will fall within that belt.

It is evident then that a relatively large number of similar and complete records are necessary before we can separate the usual or normal occurrences from the unusual occurrences of the same general kind.

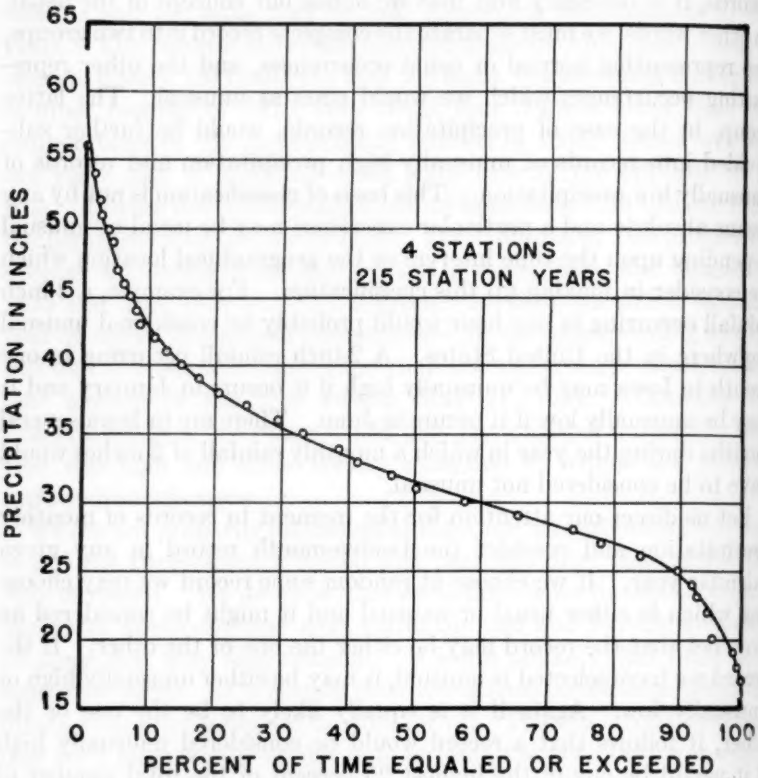

Fig. 8. Duration of Annual Precipitation—Central District

Having thus defined normal and unusual records, let us consider some of the data which are published in the Climatological Summaries for Iowa.

Figure 8 shows the annual rainfall records of four stations in the central district in Iowa arranged in order of magnitude. The stations included are Iowa Falls, Boone, Marshalltown, and Des Moines, and there is represented a total combined record of 215 station-years or

an arithmetic mean of 54 years at each station. The ordinates represent the precipitation recorded in any calendar year and the abscissas represent the percent of the total number of station-years of record that any particular annual rainfall was equaled or exceeded during the period of record. The extreme range of observations in this district extends from a maximum of about 57 inches to a minimum of about 17 inches in one year. Twenty-five percent of the total years of record exceeded about 37 inches and 25 percent of the total years of record were less than 28 inches. Accepting for the moment the definitions which were proposed earlier, annual rainfall in the central Iowa district which exceeds 37 inches would be considered unusually high and annual rainfall less than 28 inches would be considered unusually low. Furthermore, any rainfall between 28 inches and 37 inches in one year would be considered not unusual or normal. This figure also shows that it is an even bet that any annual rainfall selected from records at these stations will be greater or less than 32 inches,—the ordinate of the curve corresponding to the 50 percent abscissa.

Figure 9 shows the monthly precipitation records at these same stations analyzed in a similar manner. Curves are drawn showing the variation of monthly rainfall in each month of the year, and these curves cover the same period of record, namely 215 station-years. Selecting from these curves and from the records themselves the ordinates for each month indicated by the 0 and 100 percent abscissas, we obtain respectively the maximum and minimum monthly rainfall recorded at any one of the four stations in the district. The ordinate for the 25 percent abscissa defines the lower limit of the unusually high monthly precipitation (which is also the upper limit of the normal precipitation for that same month). The median monthly precipitation is defined by the ordinate corresponding to the 50 percent abscissa. The ordinate which corresponds to the 75 percent abscissa for any curve represents the upper limit of unusually low precipitation and also the lower limit of normal monthly precipitation for the given month. These values for the central district in Iowa, and also for the other eight districts into which the state is divided for climatological studies, are shown in table 1.

The values of monthly and annual precipitation shown in this table are compiled from climatological records. The values of monthly precipitation in the zero percent row are the greatest of record in each district. The *greatest* monthly precipitation in January, in February,

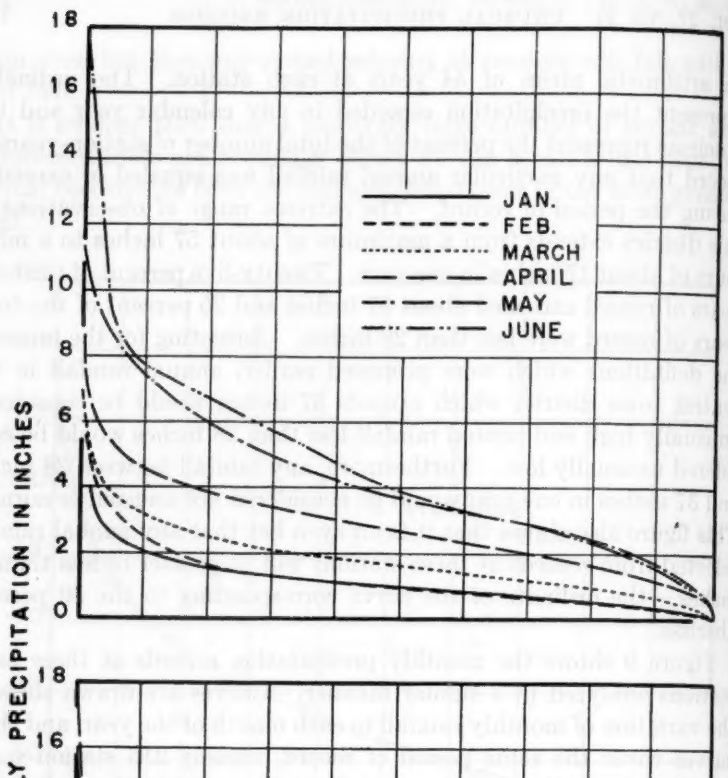

FIG. 9. DURATION OF MONTHLY PRECIPITATION—CENTRAL DISTRICT

TABLE 1

Summary of data from duration curves

Monthly and annual precipitation in Iowa

DISTRICT	PER-CENT	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
NW	0	3.4	3.5	4.0	7.7	10.7	14.7	12.0	7.6	10.9	5.2	4.9	3.2	41.8
	25	0.9	1.0	1.7	3.5	5.2	5.4	4.6	4.6	4.2	2.6	1.8	1.1	31
	50	0.6	0.6	1.2	2.3	3.6	4.1	3.0	2.9	2.9	1.6	0.8	0.6	27
	75	0.3	0.4	0.8	1.4	2.3	2.8	2.0	1.5	1.9	1.0	0.4	0.3	23
	100	0.0	0.0	0.0	0.2	0.1	0.3	0.1	0.1	0.0	0.1	0.0	0.0	11.5
NC	0	3.2	6.8	4.6	8.2	10.6	12.1	9.4	12.8	11.0	7.9	11.5	4.1	48.3
	25	1.4	1.4	2.2	3.4	5.3	5.7	4.4	4.8	5.1	2.9	2.0	1.4	34
	50	0.9	0.9	1.6	2.4	3.6	4.2	3.0	3.3	3.2	2.0	1.2	1.0	30
	75	0.5	0.5	1.0	1.6	2.5	2.8	1.8	2.2	1.8	1.3	0.6	0.6	26
	100	0.0	0.0	0.0	0.0	0.5	0.1	0.1	0.4	0.2	0.0	0.0	0.0	15.4
NE	0	3.8	7.0	6.1	8.0	15.6	16.5	14.0	12.8	12.9	10.2	6.3	5.6	55.2
	25	1.8	1.5	2.6	3.5	5.5	6.0	5.3	4.5	5.1	3.3	2.4	2.0	37
	50	1.1	1.0	1.8	2.4	3.6	4.2	3.5	2.8	3.6	2.3	1.5	1.2	32
	75	0.6	0.6	1.2	1.7	2.5	2.4	2.2	1.8	2.5	1.5	0.8	0.8	28
	100	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.2	0.0	0.0	0.0	0.1	15.0
WC	0	3.6	5.3	4.6	7.2	14.2	14.1	13.0	11.7	12.5	6.6	9.0	4.4	56.6
	25	1.2	1.2	1.9	3.6	5.2	5.8	5.0	4.8	4.6	2.9	1.7	1.4	34
	50	0.7	1.0	1.3	2.4	3.4	4.2	3.2	3.2	2.8	1.8	1.0	0.8	28
	75	0.4	0.5	0.8	1.4	2.3	2.7	2.0	2.1	1.7	1.1	0.5	0.4	24
	100	0.0	0.0	0.0	0.2	0.2	0.1	0.2	0.2	0.0	0.0	0.0	0.0	14.8
C	0	6.3	6.3	5.9	7.4	11.0	17.2	14.0	12.4	16.0	8.3	8.0	4.0	56.8
	25	1.4	1.4	2.2	3.6	5.4	6.2	4.9	5.0	5.4	3.4	2.0	1.6	37
	50	1.0	0.9	1.6	2.6	3.6	3.9	3.1	3.2	3.5	2.4	1.2	1.0	32
	75	0.6	0.6	1.0	1.8	2.6	2.6	1.9	2.0	2.2	1.5	0.6	0.6	28
	100	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.1	0.2	0.2	0.0	0.0	17.5
EC	0	8.5	5.8	9.5	11.8	12.6	14.3	13.7	14.0	12.0	9.2	7.6	7.0	57.5
	25	2.2	2.1	3.1	4.0	5.6	5.8	5.2	5.2	5.2	3.7	2.8	2.2	40
	50	1.2	1.4	2.4	2.8	3.9	4.1	3.5	3.3	3.3	2.4	1.7	1.5	35
	75	0.8	0.8	1.6	1.8	2.6	2.7	2.2	2.1	2.1	1.4	1.0	0.9	30
	100	0.0	0.0	0.1	0.2	0.8	0.2	0.1	0.0	0.0	0.1	0.0	0.1	18.8
SW	0	2.8	4.5	4.9	7.9	12.4	15.4	17.0	13.8	17.7	7.8	8.7	5.5	64.5
	25	1.2	1.4	2.0	3.4	5.1	6.4	5.5	4.6	4.9	3.4	1.8	1.4	35
	50	0.7	0.8	1.4	2.5	3.6	4.4	3.2	3.2	3.0	2.2	1.0	0.8	30
	75	0.4	0.5	0.8	1.6	2.2	3.0	1.8	2.1	2.0	1.3	0.4	0.4	26
	100	0.0	0.0	0.0	0.2	0.3	0.3	0.2	0.2	0.2	0.0	0.0	0.0	15.5

TABLE 1—*Concluded*

DISTRICT	PERCENT	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
SC	0	5.3	5.3	5.7	8.0	13.2	13.3	11.6	13.0	18.6	7.3	7.5	3.6	53.7
	25	1.4	1.6	2.2	4.1	5.2	6.3	4.9	5.0	5.4	3.6	2.1	1.8	38
	50	0.8	1.0	1.7	2.8	3.8	4.6	3.0	3.2	3.4	2.4	1.4	1.0	33
	75	0.4	0.5	1.1	1.9	2.6	3.0	1.6	2.0	2.3	1.5	0.7	0.6	29
	100	0.0	0.0	0.0	0.4	0.9	0.2	0.0	0.1	0.0	0.0	0.0	0.0	15.6
SE	0	6.1	6.1	6.0	7.7	11.8	15.6	12.7	12.3	12.9	8.3	6.0	8.6	52.1
	25	1.8	1.8	3.0	3.8	5.2	6.1	5.1	4.6	5.3	3.5	2.4	2.0	39
	50	1.1	1.2	2.2	2.7	3.7	4.3	3.2	3.2	3.4	2.2	1.6	1.3	34
	75	0.6	0.7	1.4	1.9	2.4	2.7	1.8	2.0	2.1	1.2	0.9	0.8	28
	100	0.0	0.0	0.0	0.3	0.4	0.1	0.0	0.1	0.4	0.1	0.0	0.0	16.6

in March, etc., was not recorded in any one calendar year. The greatest amount actually recorded in one calendar year is shown in the zero percent row in the last column of the table. Obviously the *sum* of monthly figures for a given percent experience has no significance and it is not equal to the yearly figure for the same percent experience.

Figure 10-*A* shows these data plotted with monthly precipitation as ordinates and corresponding months of the year as abscissas. This figure clearly shows that the winter months—December, January, and February—are normally the driest months of the year. During those months we would consider any monthly precipitation between 0.6 and 1.4 inches as a usual normal experience which might be expected on the average once in two years. The wettest month in this district is June and during that month it is an even bet that the precipitation will range between 2.6 and 6.2 inches. September is the next wettest month, and September rains may on the average be expected to bring the monthly precipitation somewhere between 2.2 inches and 5.4 inches.

In order to study annual precipitation in Iowa on the basis of this classification of normal, unusually high, and unusually low monthly records, we have selected for each of four respective stations in the several districts the wettest year, the driest year, and two years of median annual rainfall. Figure 10-*B*, -*C*, and -*D* are representative of the figures which were drawn to represent these selected data.

These figures show that the wettest years of record have been made up of a preponderance of normal months and wet months. In

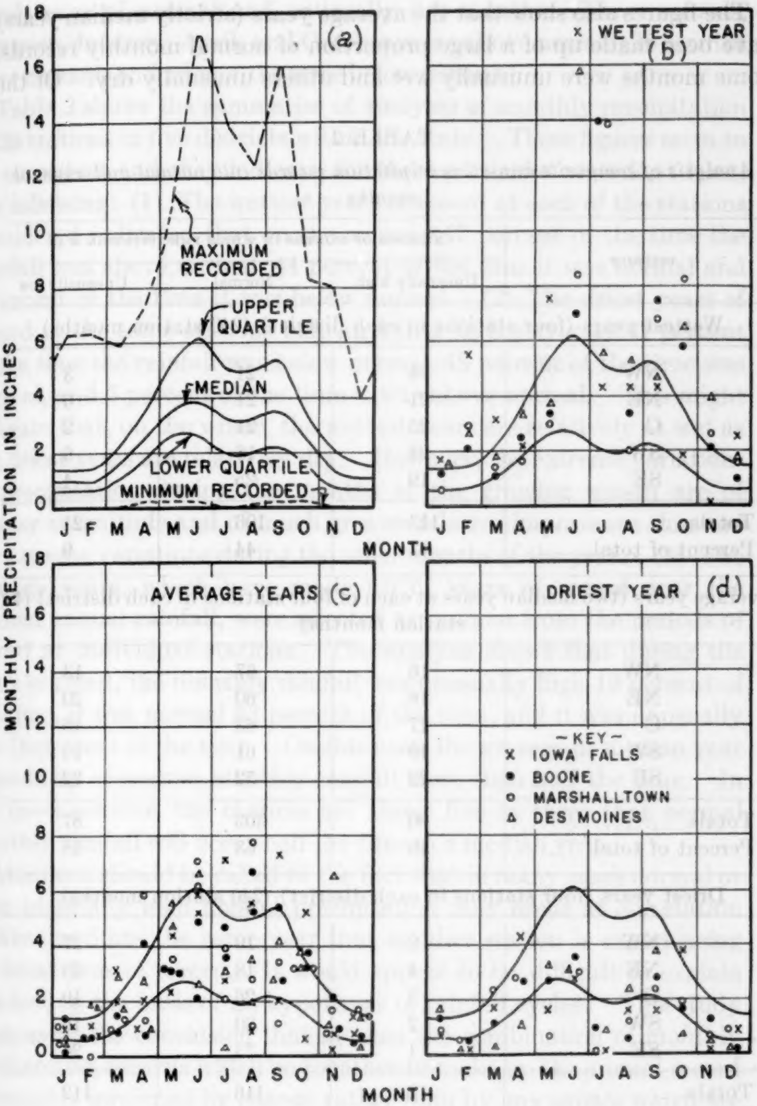

FIG. 10. MONTHLY PRECIPITATION—CENTRAL IOWA

this particular case there were two months of record below normal, one in April and the other in November. Of the 48 months of record represented in figure 10-*B*, 25 would be classed as unusually wet, 21 as normal, and 2 as below normal.

The figures also show that the average years (strictly median years) have been made up of a large proportion of normal monthly records. Some months were unusually wet and others unusually dry. Of the

TABLE 2

Analysis of composite annual precipitation records into normal and unusual months

DISTRICT	NUMBER OF MONTHS IN WHICH PRECIPITATION WAS		
	Unusually high	Normal	Unusually low
Wettest years (four stations in each district) (240 station months)			
NW	24	21	3
NE	21	21	6
C	25	21	2
SW	24	18	6
SE	19	25	4
Totals	113	106	21
Percent of total	47	44	9
Average years (two median years at each of four stations in each district) (480 station months)			
NW	16	67	13
NE	16	60	20
C	17	63	16
SW	19	61	16
SE	22	52	22
Totals	90	303	87
Percent of total	19	63	18
Driest years (four stations in each district) (240 station months)			
NW	2	19	27
NE	4	18	26
C	3	26	19
SW	2	30	16
SE	1	23	24
Totals	12	116	112
Percent of total	5	48	47

96 months plotted in figure 10-*C*, 17 were unusually wet, 63 were normal, and 16 were unusually dry.

In the driest years of record at these same stations there was a pre-

ponderance of normal and unusually dry months. Three records, however, January, April, and October, were above normal, 26 months were normal, and 19 months were below normal.

Table 2 shows the summaries of analyses of monthly precipitation at 20 stations in five districts within the state. These figures seem to be consistent and they indicate, for these particular records at least, the following: (1) The wettest years of record at each of the stations considered indicated that on the average 47 percent of the time the rainfall was above normal, 44 percent of the time it was normal and 9 percent of the time it was below normal. (2) The driest years of record at the same stations indicated that on the average 47 percent of the time the rainfall was below normal, 48 percent of the time was normal, and 5 percent of the time it was above normal. This might indicate that, on the whole, the wettest years are relatively as wet as the driest years are relatively dry. However, the extreme variations in precipitation during the months of the growing season are of greater magnitude and of much greater relative importance than are the extreme variations during the other months of the year. (3) The average years, which were made up of years of record near the median annual rainfall, were selected at random from the periods of record at individual stations. The analysis shows that during the years selected, the monthly rainfall was unusually high 19 percent of the time, it was normal 63 percent of the time, and it was unusually low 18 percent of the time. On this basis the average or median year is made up of normal monthly rainfall more than half the time. In the cases selected the chances are about five to three that normal monthly rainfall will occur half the time in a median year.

Attention should be called to the fact that in many cases normal or even unusually high annual precipitation may occur at one station within the State the same year that another station is experiencing its driest year of record. It would appear to be difficult to explain this fact on the basis of an hypothesis of rainfall cycles. This study leads us to the conclusion that at least the combination of monthly precipitation records which go together to make up the annual record is probably governed by chance rather than by any causes which are cyclic in their effect.

SUMMARY AND CONCLUSIONS

1. The mean annual precipitation for the state of Iowa, based on records of some 100 rainfall stations, is approximately 32 inches. The

mean annual precipitation at individual stations ranges from about 26 inches in the northwest part of the state to 36 inches in the southeast part.

2. The year 1881 was the wettest calendar year of record for the state at large although many individual stations recorded greater amounts in other years. The average precipitation over the entire state was 44.2 inches. Precipitation over smaller areas was found to range from a minimum of 34 inches to a maximum of 58 inches.

3. The year 1910 was the driest calendar year of record for the state at large, although many stations recorded lesser amounts in other years. The average precipitation over the entire state was 19.9 inches. Precipitation over smaller areas was estimated to range from a minimum of less than 14 inches to a maximum of more than 26 inches.

4. The year ending May 31, 1934, was drier and hotter than the calendar year 1910. The average precipitation over the entire state was 19.4 inches with a minimum of 13 inches in the east-central portion.

5. The foregoing analysis of long term monthly and annual precipitation records for selected Iowa stations has led to a basis for classifying records as unusually low, normal, or unusually high.

6. No record of annual precipitation made up exclusively of unusually high or unusually low months has been found in the climatological summaries for Iowa. It seems reasonable to conclude, therefore, that even greater extremes of both wet and dry years must be expected in the future.

ACKNOWLEDGMENT

The duration curves of monthly and annual precipitation used in this analysis were prepared by a staff engaged in Precipitation and Flood Studies, a sub-project of the Water Resources Division of the Iowa State Planning Board. Professor A. C. Trowbridge, State Geologist of Iowa, is chairman of the Water Resources Division of the Board. The sub-project is carried on in coöperation with the Iowa Institute of Hydraulic Research under the direction of the senior author. Grateful acknowledgment is made to Edward Soucek, Leland Garrett, and Lila Cornwall for their services in compiling the basic data.

(*Presented before the Missouri Valley Section meeting, November 9, 1934.*)

TRENDS IN STREAM POLLUTION RESEARCH AND CONTROL

By J. K. Hoskins

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Although the advance in our knowledge of stream pollution and progress in the application of control measures during the past decade may have appeared erratic at times, yet, considered in its broader aspects, a definite gain has been made in the direction of improvement of procedures, both administrative and technical, for conservation of our water resources. It is to be expected that such advances will be more or less orderly, influenced as they are by changes in the intensity of public interest, governmental support and industrial activity. A review of some of the more important developments in the field of stream sanitation is the purpose of this paper.

LEGAL AND ADMINISTRATIVE TRENDS

Federal status

Under existing law the Federal Government exerts no direct administrative control over water pollution, excepting only (*a*) where such pollution may interfere with or obstruct navigation and (*b*) the discharge of oil into navigable waters. Except in the case of New York Harbor and adjacent waters, no special organization is maintained by the United States for the detection of violations of these laws. Inasmuch as the War Department supervises the improvement and maintenance of navigable rivers and harbors, its officers and employees are largely responsible for investigations of violations of these statutes, aided by officers of the Customs and Coast Guard Services. The interests of the Public Health Service, a Bureau of the Treasury Department, in stream pollution are confined to research investigations and to coöperation with state and other control agencies. To a lesser extent the Bureau of Mines and the Bureau of Fisheries have been concerned with the fact finding features of the problem.

State authority

Under our Constitution, all powers not specifically delegated or assumed by the Central Government are reserved to the States and so it is that the burden of administrative control of stream pollution now rests with the individual states. However, there has been no well defined future policy of jurisdiction laid down as between Federal and State authorities and, as stated by a Committee of the American Society of Civil Engineers (1):

"There is a growing consciousness among the States that have interstate streams . . . that the question of Federal vs. State control of navigable unappropriated waters should be definitely determined."

The present tendency, not only upon the part of the States, but of the Federal authorities as well, appears to favor State control. This attitude is clearly expressed by the Chief of Engineers, U. S. Army, and concurred in by the Secretary of War (2) reporting upon pollution affecting navigation:

"It is believed that should the Federal Government undertake the control of pollution generally, there might be a tendency on the part of states and local authorities to relax their efforts to study the problem and to enforce local laws. . . . Federal assistance and coöperation will in my opinion produce more beneficial results with less attendant injury to the development of cities and industries than will general Federal legislation."

This trend toward State control has resulted, not primarily because of the logical, strategic position of individual States for policing their own waters, but largely from the increasingly active assumption of this responsibility by groups of States in cases of interstate waters as well as by individual States in intrastate water pollution.

Interstate agreements

Of outstanding significance and promise is the increasing tendency for States to enter joint agreements for the sanitary control of their interstate waters. Such agreements may be either one of two general types, (1) formal treaties or (2) less formal coöperative arrangements entered into by State administrative officers.

Interstate treaties for the control of water pollution, are a recent application of a power that has always existed under the Constitution, whereby States may enter into formal compacts which, upon approval by Congress, become valid. As stated by Carpenter (3) such com-

pacts, usually phrased in the manner of international treaties, are prepared by representatives or commissioners of the signatory States and become effective upon approval by the legislature of each of the signatory States and by the Federal Congress. Where the problem is simple such compacts may be made by direct legislative acts, one State legislature by its act making an offer which is accepted by act of the legislature of the other State. Such offer and acceptance, with the consent of Congress, constitutes a compact between the States. Because of the binding nature of such formal treaties it is well to bear in mind as the American Society of Civil Engineers Committee (1) warns that:

"Experience indicates that it would be more difficult to change or modify provisions embodied in State Compacts, once they have been agreed to, than if the adjustments were the result of a Court decree. . . . While, as stated, it is believed that a compact or treaty is the more logical method for settling questions arising between States . . . it is essential to approach such questions with ample caution and that compacts should be signed or ratified only after the most mature deliberation of the ultimate effect which the same may have upon the future welfare of the peoples, since, when once ratified, such compacts may be practically irrevocable."

An example of such a formal compact is that in process of enactment between the States of New York, New Jersey and Connecticut, which was drafted as the result of findings by a research and engineering committee that made a study of the sanitary condition of the coastal waters to be included. As now proposed, five commissioners from each State are to constitute a sanitation commission which is empowered to classify the uses of all waters under its jurisdiction, issue orders for treatment of sewage where deemed necessary and to stop water pollution by injunction proceedings. The commission does not have authority to construct sewage disposal plants, the individual States being responsible for carrying out the mandates of the commission.

Less formal agreements between appropriate State agencies for the control of pollution of interstate waters are perhaps more numerous. Of this type is the Ohio River Interstate Stream Conservation Agreement entered into by the State Health Commissioners of Ohio, Pennsylvania, West Virginia, Kentucky, Indiana, Illinois, New York, Maryland and Tennessee for the purpose of coöperation in the abatement of pollution in one State harmful to public interests in any of the others. By formal resolution (4) these health commissioners

constituted the Chief Engineers of their respective health departments a "Board of Public Health Engineers of Ohio River Basin" to carry out the letter and spirit of coöperation and conscience upon which the Ohio River Interstate Stream Conservation Agreement is founded. This Board is charged with the duty of recommending to their commissioners policies and procedures for making the agreement effective, and specifically of controlling the discharge of phenol wastes into the Ohio River and its tributaries.

An agreement formed along the same general lines includes the States bordering the Great Lakes and known as the Great Lakes Drainage Basin Sanitation Agreement (5) for the purpose of coöperating "with each other and with the United States Public Health Service in carrying out a policy for the improvement of the quality of the waters of these interstate lakes and their tributary streams wherever necessary in these States, the prevention or correction of undue pollution thereof, to the end that the said lakes and tributary streams may be maintained or rendered suitable sources of public water supplies."

Other interstate agreements or compacts for the conservation of water resources are discussed by Mendelsohn (6), Carpenter (3), Saville (7) and by Committees of the American Society of Civil Engineers (1), and of the Conference of State Sanitary Engineers (8).

State laws

The elements of appropriate State statutes for conservation of water resources have been formulated by the Conference of State Sanitary Engineers and have been endorsed by the Conference of State and Provisional Health Authorities of North America (9). In these recommendations consideration of the practical and economic features of the problem are stressed in the drafting of legislation and broad, fundamental principles are stated upon which such legislation should be based and administered. Of particular interest is the recommended order of importance of use of public waters stated as (1) sources of present and future public and municipal water supplies, (2) sources of water for industry and agriculture and (3) recreation.

Distinct progress has been made by the States in clarifying and augmenting their legal authority in matters of stream sanitation control. Noticeable trends in this field include the establishment of regulatory authority with provision for its continued administration, formation of sanitary districts for more efficient handling of commu-

nity problems than is possible within restricted political boundaries, and creation of sources of operating revenue for sewage treatment plants.

Although the laws dealing with stream pollution are not equally comprehensive in all States, practically all of them have given the subject some attention (2) (7). Such legislation is being progressively improved and strengthened, designating for its enforcement either existing agencies such as State Departments of Health or newly created commissions or boards. In 1925 Baker (10) found that, of forty-two states reporting, control of stream pollution was vested solely in the State Board of Health in twenty-two and partly in eleven, other commissions in three and no definite jurisdiction in six. In 1931, Saville (7) reports that in nineteen States the Health Department had sole jurisdiction, in seventeen States jointly with other administrative divisions, in six States such powers were assigned to other commissions, while six States had assumed no jurisdiction. From this it would appear that the trend is toward a division of responsibility for control and toward the creation of special commissions or boards for this specific function. It should be pointed out, however, that generally the State Department of Health is represented on the newly created commissions. Thus, the Pennsylvania Sanitary Water Board (11) is composed of the Secretary of Health as Chairman, the Secretary of Forests and Waters, the Commissioner of Fisheries and three appointees of the Governor and has for its Chief Engineer and Secretary the Chief Engineer of the State Health Department. The West Virginia State Water Commission, the Wisconsin Water Pollution Committee, the Michigan Stream Control Commission and the Illinois Sanitary Water Board are somewhat similarly constituted.

The creation of Sanitary Districts by State legislation has shown continued progress. By this means legal authority is conferred upon metropolitan areas for a more comprehensive solution of their specific problems and for elimination of the frequently perplexing situations arising from political boundaries between adjacent municipalities. Such legislation may be of an inclusive nature authorizing the establishment of conservancy or sanitary districts within the State jurisdiction upon compliance with certain conditions such as is in force in Illinois (12) or may be enacted for the benefit of some specific section or watershed area. The many advantages of such unified procedures for sewage treatment and stream pollution abatement within the same

community or drainage area are obvious. Usually such sanitary districts are granted separate powers of taxation which provide operating revenue independent of the appropriations of component political units within the district boundaries.

Another well defined trend is the enactment of State laws authorizing municipalities to levy taxes for sewerage service, the proceeds to be applied to the maintenance and operation of sewerage systems and sewage treatment plants. Childs and Schroepfer (13) have made an exhaustive study of sewer rental laws and charges in the various States. They found that by 1932, twenty-six States and the District of Columbia had either enacted sewer rental laws or had legal authority for making such charges for sewer service. The charges are based "either upon the quantity of water used, the number and type of plumbing fixtures, the number of persons served, the type of premises, the character of the sewage or upon a combination of one or more of these methods." In 1931 a total of 328 municipalities in the United States had ordinances providing for sewer rental charges.

Administrative features

An encouraging development in water pollution control has been the increased understanding and willingness to coöperate in the solution of specific problems upon the part of industry and Government. The older policy of indiscriminate coercion of polluters by attempted enforcement of drastic laws has given way almost completely to that of coöperative agreements between industry and administrative agencies for the scientific study and application of practicable measures for stream improvement. The widespread advances resulting from this enlightened policy are sufficient proof of its efficacy. Notable examples of progress obtained by such procedures as recorded in the literature include Pennsylvania (11), Wisconsin (14), the Ohio River Basin (15) and numerous others. The extent to which such coöperative action may be built up with limited public funds is illustrated by the State of Virginia (16) (17) where industry sponsored a comprehensive stream survey program aided by educational institutions and other interested bodies under the leadership of the State Department of Health.

There has been advance also on the part of administrative and legislative agencies in the clearer definition of the relative values of water usage, the classification of waters and the consideration of

limiting standards of water degradation. Except in special instances the highest use of water is generally conceded to be for drinking purposes, which at once gives precedence of stream sanitation over both limited and indiscriminate pollution. However, where streams are not needed for this prime purpose, economic necessity may and does dictate their usage for carriers of domestic and industrial sewage and for industrial, recreational, agricultural and navigation purposes. It is, therefore, being increasingly recognized that classification of all waters is helpful to administrative agencies in determining the nature of use to be permitted. The Sanitary Water Board of Pennsylvania was perhaps the first State control agency to establish and put into effect, on a State wide basis, this principle of stream classification (18). All waters of the State are grouped as:

Class A. **Relatively clean and pure streams, unpolluted or uncontaminated from any artificial source, suitable for domestic water supply after chlorination. Artificial pollution of such streams is prohibited and a high degree of treatment of any sewage or industrial waste is required before its discharge into them.**

Class B. **Streams in which pollution shall be controlled, the degree of control to be dependent upon the general public interests and economics in each particular case.**

Class C. **Streams so polluted that their control or recovery is not economically feasible or advisable beyond the prevention of nuisance or menace to health.**

Earlier specifications for the restriction or control of pollution were generally expressed in terms of limits of strength of polluting wastes or requirements for the degree of their treatment prior to discharge into the receiving body of water. The trend is now definitely toward at least equal attention to the resulting effect of such polluting substances upon the receiving stream rather than to regard solely for their quality and degree of previous purification. This change of viewpoint is illustrated by comparison of previously expressed standards of pollution limits such as those based on dilution volume per population unit or percentage of solids removal with the later suggested standards incorporated in the Tri-State Compact in process of enactment above mentioned. These proposed standards of purity for the tidal waters covered by the treaty between New York, New Jersey and Connecticut (19) specify that two general classifications shall be used:

"1. *Class A*, in which the designated water areas are expected to be used primarily for recreational purposes, shellfish culture or the development of fish life.

"2. *Class B*, in which the designated water areas are not expected to be used primarily for recreational purposes, shellfish culture or the development of fish life.

"No sewage or other polluting matters shall be discharged or permitted to flow into, or be placed in, or permitted to fall or move into the tidal waters of the Treaty Area, except under the following conditions and restrictions:

"1. All sewage discharged or permitted to flow into the waters of Class "A" shall first have been so treated as:

"(a) to remove all floating solids and at least 50 per cent of the suspended solids; and

"(b) to effect a reduction of organisms of the B. coli group (intestinal bacilli) so that the probable number of such organisms shall not exceed one per cubic centimeter in more than 50 per cent of the samples of sewage effluent tested by the presumptive method, except that in the case of discharge into waters used primarily for bathing this bacterial standard need not be required except during the bathing season; and

"(c) to effect a reduction in the oxygen demand of the sewage effluent sufficient to maintain an average dissolved oxygen content in the tidal waters of the Treaty Area and in the general vicinity of the point of discharge of the sewage into those waters, at a depth of about 5 feet below the surface, of not less than 50 per cent saturation during any week of the year.

"2. All sewage discharged or permitted to flow into the waters of Class "B" shall first have been so treated as:

"(a) to remove all floating solids and at least 10 per cent of the suspended solids, or such additional percentage as may by reason of local conditions be necessary to avoid the formation of sludge deposits in the Class "B" waters of the Treaty Area: and

"(b) to effect a reduction in the oxygen demand of the sewage effluent sufficient to maintain an average dissolved oxygen content in the tidal waters of the Treaty Area and in the general vicinity of the point of discharge of the sewage into those waters, at a depth of about 5 feet below the surface, of not less than 30 per cent saturation during any week of the year."

Many of the State control agencies are also exercising the power of review and approval of plans for the installation or extension of sewerage and sewage treatment works, thereby placing a check on the adoption of uneconomical or unsuitable methods of sewage disposal by local communities. Although licensing of sewage works operators by the States has not gained rapidly, many States are finding it possible to encourage the employment of technically trained, qualified persons for such positions and to insure their tenure of office during changes in local political government. Such activities provide more consistent and efficient treatment of municipal sewage and further the State wide program for alleviation of stream pollution.

PROGRESS IN STREAM POLLUTION RESEARCH

In its broader sense water pollution embraces on one side the sanitary protection of drinking water supplies derived from impure surface sources and on the other, the economic and sanitary disposal of municipal and industrial liquid wastes, all of which must be discharged eventually into some stream or other body of water. In any comprehensive discussion of stream pollution research, therefore, the subject may be separated logically into three main divisions: (*a*) stream pollution and natural stream purification proper, (*b*) water purification, and (*c*) sewage treatment and disposal. However, reviews of progress on the second and third of these divisions appear frequently in the literature and are quite complete, so that they need not be considered in any detail here.

Research in water pollution has been greatly stimulated in this country during the last two decades, following the earlier English and German investigations, as a result of our rapidly increasing urban populations and growth of industry with their attendant problems of liquid wastes disposal. Numerous agencies have taken part in these activities. The most extensive program in this field of research perhaps has been that of the U. S. Public Health Service which originated in 1912 with the legislative authorization for the Service to investigate the pollution, either directly or indirectly, the navigable streams and lakes of the United States. Surveys of the Potomac River (20) and of the Atlantic coastal waters were undertaken (21) (22) and headquarters for a study of the Ohio River were established at Cincinnati. Upon the completion of the Ohio River studies proper (23), this station was maintained as the headquarters of stream pollution research activities and since then has been engaged not only in field investigations of stream pollution but in experimental and laboratory research of fundamental factors operative in sewage treatment and water purification. The scope of these Federal activities was discussed by Frost (24) in 1926 and has followed the same general course since that time, the results being published from time to time in the form of Public Health Bulletins and articles in Public Health Reports and various technical journals.

Many States also have supported research studies connected with their specific problems of stream pollution acting through their health departments or other special boards either alone or in cooperation with industrial groups. Metropolitan districts, educational institutions, municipalities and commercial interests have

likewise added to the fund of available knowledge on the subject. The coöperation of industry in such studies in endeavors to alleviate the detrimental effects of their liquid wastes when discharged to streams, is a most promising trend.

By extended observations of (*a*) the effect of known amounts of pollution contributed to streams of determinable flow characteristics and of (*b*) the biological and biochemical changes in these streams brought about during periods of recovery from such pollution, the complex relationships and interplay of physical and biological factors which operate in the processes of stream pollution and natural purification are becoming better understood. Such information, supplemented by that contributed from collateral studies, has provided a means for evaluating pollution in terms of its effect upon the receiving water body and for determining with some degree of accuracy, the capacity of streams for pollution without the creation of objectionable conditions. Urgent need for the solution of the problems of various polluted waterways has stimulated research in this field and is likely to continue to be a driving force as our urban population increases. The development of the best thought on the subject of stream pollution capacity and recovery may be traced through the published results of such studies as those of the Great Lakes, New York harbor and the Hudson River, the Chicago Drainage Canal and the Illinois River, the Ohio River and the Upper Mississippi River. In tracing this progress it is necessary to distinguish clearly the two types of stream purification which, although closely related and to some extent interdependent, are nevertheless distinct: First, that which has to do with the oxygen relationships and changes in form of other constituents during the progress of digestion of the putrescible organic matter of sewage and other polluting matter, and, second, that which is concerned with the reduction in bacterial content added by sewage. The major factors which affect these two types of stream purification capacity have been reviewed by Streeter (25). Proposed methods for evaluating these factors and procedures for applying them to the solution of specific problems are widespread through the literature on the subject. As Streeter concludes:

"With the increasing stress being imposed on the natural purification capacities of our streams and the consequent reduction in the margin of safety hitherto inherent in them, a general tendency toward the adoption of more rigid standards for the efficiency of water and sewage treatment is being evidenced. For the designer and plant operator this tendency means larger responsibilities, and an ever broadening horizon of knowledge and experience."

The relation of stream pollution to public water supply must become more closely drawn as time goes on. Trends in this direction are indicated by the general demand for clearly defined standards of drinking water supplies and for the insistence upon the observance of such requirements. The justification of such demand is demonstrated by the effectiveness of water borne disease control where these standards are enforced and the increase of such disease rates where they are relaxed. There is still need perhaps, for more precise determination as to whether the present standard should be advanced, although the study of Veldee (26) indicated that under the conditions which he investigated, cases of typhoid could not be traced to water supplies which conformed to the present established limits of bacterial content.

This intimate relation between stream pollution and drinking water supply, even where the water purification plant intervenes, has been demonstrated by Streeter (27). In extended observations of full scale plant, analytical data which were confirmed by results from a large scale experimental water filtration plant, a consistent relation was found to exist between the bacterial content of the raw water and that of the effluent of various stages of the treatment process including final disinfection. In other words, there are well defined limiting loads of bacterial pollution that the water purification plant may be expected to handle and at the same time produce an effluent meeting the drinking water standard. These limiting numbers of B. coli in Ohio River water, from which effluents can be produced meeting the primary requirement of 1 B. coli per 100 cc. by various combinations of treatment are:

Character of treatment	*Limits of B. coli per 100 c.c.*
(1) Chlorination alone	80
(2) Coagulation, sedimentation and rapid sand filtration	80
(3) Same as (2) with prechlorination	3,500
(4) Same as (2) with postchlorination	6,000
(5) Same as (2) with both pre- and post-chlorination	20,000
(6) Same as (4) with double stage sedimentation	60.000

There is an increasing need for consideration of the less fatal, but yet equally disturbing effects upon the public health that are resulting from the use of treated waters from contaminated sources. Changes in the rates of occurrence of intestinal infections such as enteritis among users of public water supplies correlate in many instances quite closely with known changes in the B. coli content of the drink-

ing water, which seems to indicate that endemic rates of such diseases are quite sensitive to water quality. There are occurring also less severe but none the less widespread and sudden epidemics of intestinal disturbances that are believed to be of non-bacterial origin but which result from some chemical or other irritant in the drinking water supply such as those investigated by Veldee (28). The damaging effect upon the teeth of fluorides present in drinking waters in many parts of the country is another of the problems that is of serious concern. These, among other dangers, lurking in the treated, but not purified, drinking water supplies obtained from contaminated sources, urge us to extend our endeavors to cope with the potential and real menace of stream pollution.

CONCLUSION

Summing up these various trends it seems fair to conclude that legislative bodies are accepting their responsibility for the creation and financial support of properly constituted authorities for the establishment and prosecution of comprehensive policies of stream sanitation. Such stream control agencies are functioning over increasingly wider areas. The tools with which to make more effective and efficient the practical application of these policies are being supplied to both administrative and plant operation officials through progress in research. The need for such well directed research is, therefore, a continuing one.

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FILTER SAND EXPERIMENTS

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Early in 1932, experiments were started at the Island Filtration Plant in Toronto, in co-operation with a number of other cities, under the Chairmanship of James W. Armstrong, of Baltimore, to obtain data concerning the filtering properties of different grades of sand. The results of these experiments are presented, not with the idea that they should be applied directly to large filters, but that, after making suitable allowances, engineers may be aided in the design and operation of filters.

FILTER BEDS OF GRADED SAND

It was arranged to perform experiments to determine, for the various sizes of sand, the ability of the filter bed to prevent the passage of floc, length of run, effect of temperature on length of run, most effective washing rate, effect of temperature on washing rates, sand rise data, depth of penetration of floc, effect of temperature and viscosity on sand rise, and the extent of hydraulic grading.

Operating conditions, etc.

In order to assure uniform operating conditions it was agreed that the filters should be clean prior to each run, the applied water should be properly treated, and the effluent should be clear. Clear water was defined as water containing less than 0.2 p.p.m. turbidity. Properly treated water contains no colloidal turbidity.

It was agreed to terminate filter runs when the loss of head reached 8 feet or when the effluent turbidity reached 0.2 p.p.m. The rate of filtration was kept constant at 125 million U. S. gallons per acre per day.

Frequent determinations were made of the turbidities of raw, applied and filtered waters.

Description of apparatus

The filters consist of eight Pyrex glass tubes approximately 1¾-inches inside diameter and 5 feet long, set up in a wooden framework and accurately plumbed. Eight gradings of sand, arbitrarily selected,

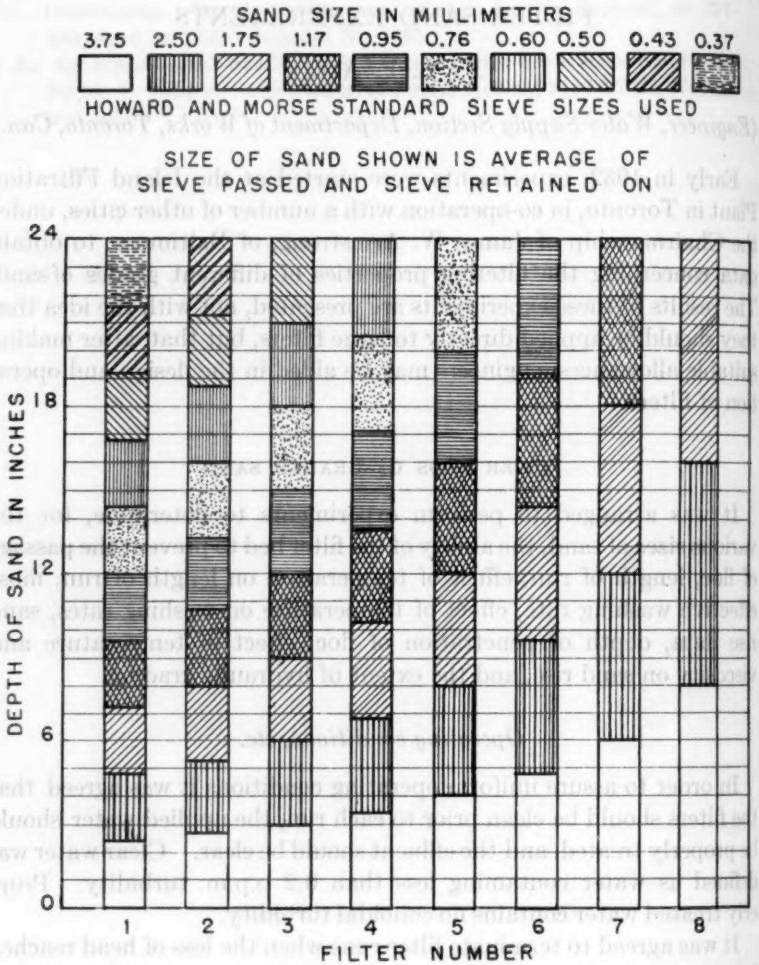

FIG. 1. DEPTH AND GRADING OF SAND USED IN SMALL EXPERIMENTAL GLASS FILTERS

covering more than the entire practical range, were placed in the filter tubes in a manner designed to produce identical beds in all cities. The beds were 24 inches deep, graded as shown in figure 1.

Filtration

Filter runs were conducted during a period of approximately one year in order to include the various conditions of the raw water due to seasonal changes. The lengths of runs are shown in table 4 and a

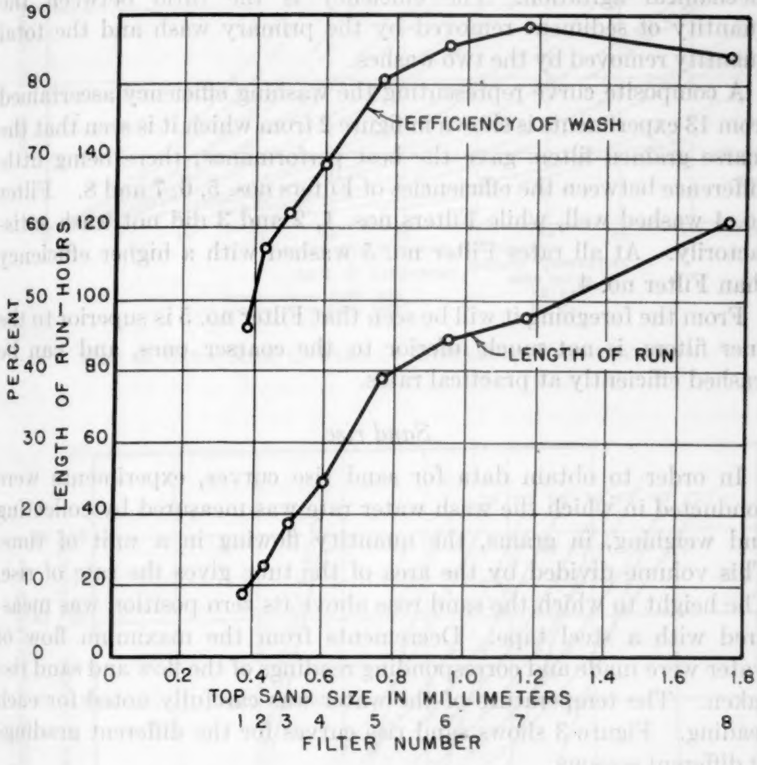

FIG. 2. EFFICIENCY OF WASH AND LENGTH OF RUN
Average of results from 13 runs

composite curve of these data plotted against top sand size is shown in figure 2.

The results of these experiments show that there is a progressive increase in length of run from Filter no. 1 to Filter no. 8, and that the length of run, for Filters nos. 1 to 5, inclusive, is practically proportional to the size of the sand grain.

Filter washing

A method of expressing efficiency of filter washing was devised, using two washes; a primary wash corresponding to routine used in regular practice, and a secondary wash, in which the filter was thoroughly cleaned by means of an ample quantity of wash water and mechanical agitation. The efficiency is the ratio between the quantity of sediment removed by the primary wash and the total quantity removed by the two washes.

A composite curve representing the washing efficiency ascertained from 13 experiments is shown in figure 2 from which it is seen that the coarse grained filters gave the best performance, there being little difference between the efficiencies of Filters nos. 5, 6, 7 and 8. Filter no. 4 washed well, while Filters nos. 1, 2 and 3 did not wash satisfactorily. At all rates Filter no. 5 washed with a higher efficiency than Filter no. 4.

From the foregoing it will be seen that Filter no. 5 is superior to the finer filters, is not much inferior to the coarser ones, and can be washed efficiently at practical rates.

Sand rise

In order to obtain data for sand rise curves, experiments were conducted in which the wash water rate was measured by collecting and weighing, in grams, the quantity flowing in a unit of time. This volume divided by the area of the tube gives the rate of rise. The height to which the sand rose above its zero position was measured with a steel tape. Decrements from the maximum flow of water were made and corresponding readings of the flow and sand rise taken. The temperature of the water was carefully noted for each reading. Figure 3 shows sand rise curves for the different gradings at different seasons.

Temperature and viscosity

Probably everyone connected with water purification knows that variations in viscosity of water due to temperature changes effect corresponding variations in the rise of sand during a wash, but the full extent of the change due to seasonal fluctuation in water temperature may not be fully realized.

In order to demonstrate the influence of viscosity, sand rise experiments were conducted on Filter no. 1 at various temperatures of wash water. A set of readings were taken at every ten degrees between

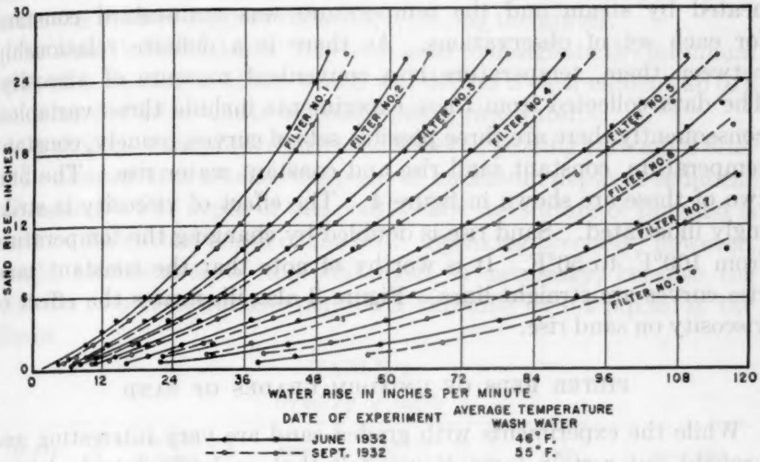

Fig. 3. Sand Rise Curves at Different Temperatures

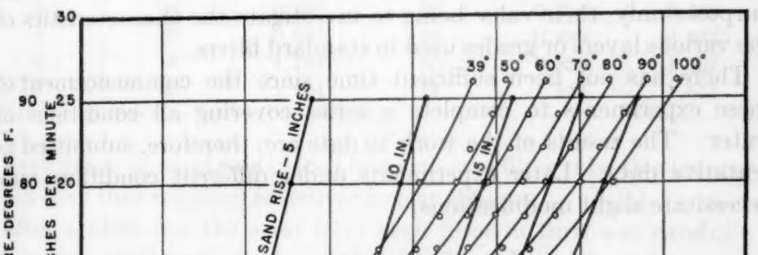

Fig. 4. Sand Rise Curves Filter No. 1 at Various Temperatures

40°F. and 100°F., inclusive. For this purpose the wash water was heated by steam and the temperature was maintained constant for each set of observations. As there is a definite relationship between them, temperature is a convenient measure of viscosity. The data collected from these experiments include three variables; consequently there are three possible sets of curves, namely, constant temperature, constant sand rise and constant water rise. The first two of these are shown in figure 4. The effect of viscosity is strikingly illustrated. Sand rise is doubled by changing the temperature from 100°F. to 50°F. It is worthy of note that the constant sand rise curves are straight lines. Figure 3 also illustrates the effect of viscosity on sand rise.

FILTER BEDS OF UNIFORM GRADES OF SAND

While the experiments with graded sand are very interesting and brought out certain facts, it was felt that no basic data had been obtained. Experiments on beds of uniform grades of sand were, therefore, undertaken from which it is hoped to deduce the performance of any grading of sand. These beds are for experimental purposes only, their value being to investigate the characteristics of the various layers or grades used in standard filters.

There has not been sufficient time since the commencement of these experiments to complete a series covering all conditions of water. The results of the work to date are, therefore, submitted as tentative data. Later experiments under different conditions may necessitate slight modifications.

Separation into grades

To simplify the practical application of the experiments the sand was separated into six grades by means of a set of Tyler's square root ratio sieves, and the size of each grade was designated by the nominal rating of the sieve through which it just passes. The sieving was prolonged to ensure complete separation.

Penetration of sediment and critical depths of filter media

A standard rapid sand filter bed may be considered to be divided roughly into two parts, viz.—the filtering medium wherein the process of filtration takes place and the supporting medium which prevents the upper layers of sand from passing into the under drains. As these

experiments are intended to apply to filtering media only, a brass screen was used to support the sand, replacing the gravel.

The term "critical depth" has been used to designate the minimum depth of a filtering medium which will deliver a clear effluent up to a loss of head of 8 feet under all conditions of raw water.

It is obvious that properly treated water in passing through a filter will be clear after it reaches the point of maximum depth of sediment penetration. The depth of this point below the surface of the sand is therefore the critical depth of the bed. Speaking precisely, however, a slight modification of this statement is necessary, because the definition of a clear effluent permits a turbidity of 0.2 p.p.m. in the effluent.

TABLE 1

Grading of sands

GRADE	PASSES SIEVE NUMBER	SIZE	CAUGHT ON SIEVE NUMBER	SIZE	SAND SIZE
		mm.		*mm.*	*mm.*
1	48	0.295	65	0.208	0.295
2	35	0.416	48	0.295	0.416
3	28	0.589	35	0.416	0.589
4	20	0.833	28	0.589	0.833
5	14	1.167	20	0.833	1.167
6	10	1.651	14	1.167	1.651

Each grade of sand was placed in a separate filter tube to a greater depth than that required to deliver a clear effluent.

After a filter run the sand from each filter in turn was carefully removed in small sections of equal height, the sediment in each section was washed out with clear water, and the turbidity and volume of the wash water were determined. The height of each section, the position in the filter from which it was taken and the product of turbidity times volume of the wash water were recorded and curves were plotted. A typical curve of distribution of sediment in the beds is shown in figure 5. The depth of penetration is the point where the quantity of sediment becomes negligible and is arbitrarily defined as the depth where the concentration of sediment is equal to twenty "turbidimilligrams" per inch of depth of sand. The quantity "turbidity times volume" of water occurrs so frequently that it is convenient to have a term to designate it. "Turbidimilligram" was coined for this purpose and is defined as the quantity of suspended

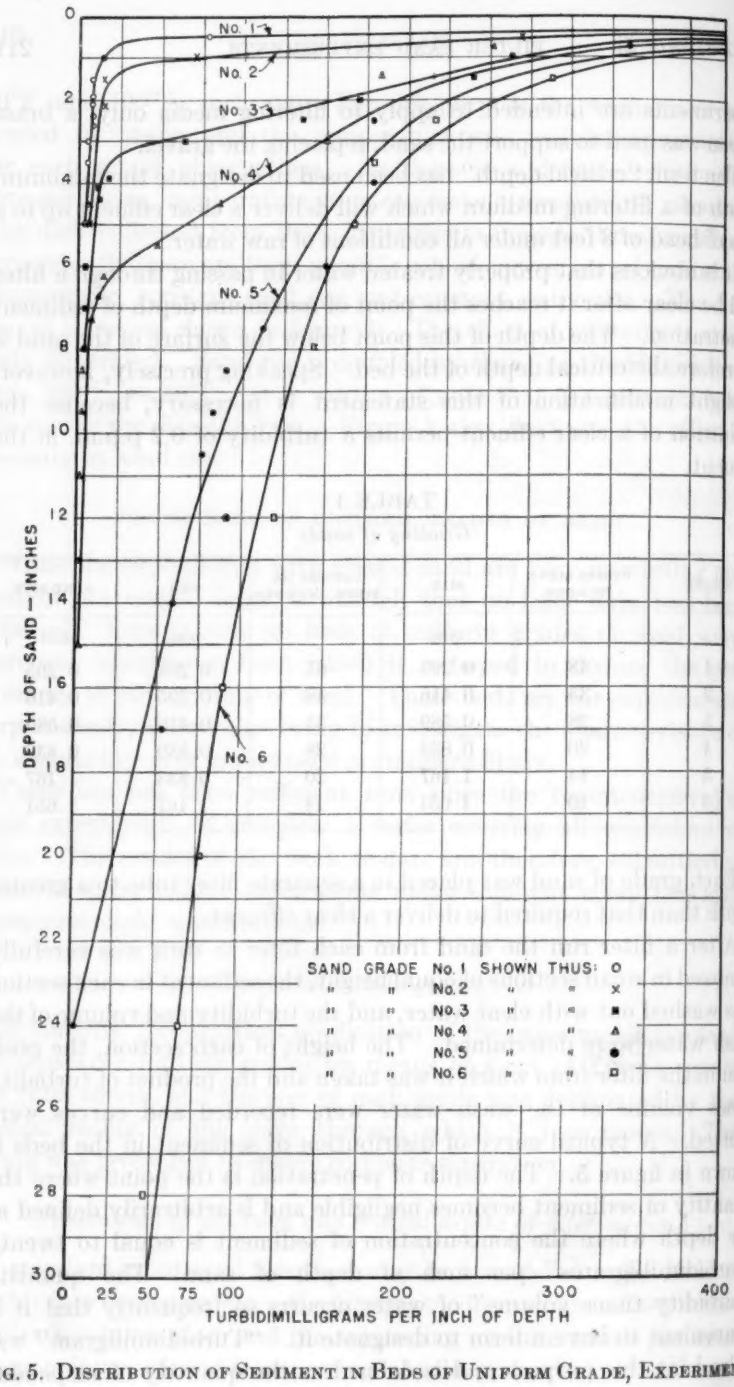

FIG. 5. DISTRIBUTION OF SEDIMENT IN BEDS OF UNIFORM GRADE, EXPERIMENT No. 5

matter in a litre of water having a turbidity of one part per million. It is a variable unit dependent on the co-efficient of fineness and is, therefore, not an absolute unit of weight. Its usefulness is based on the assumption that the co-efficient of fineness is approximately the same for all the samples under consideration.

The results of several experiments are tabulated in table 2.

TABLE 2

Depth of sediment penetration in uniform grades of sand

	GRADE NUMBER					
	1	2	3	4	5	6
Size of sieve passed, m.m.	0.295	0.417	0.589	0.833	1.167	1.651
Silt penetration, inches:						
Experiment 2	3	3.5	4.5	8	13.5	28
Experiment 3	4	4.2	6.4	9.1	15.6	42
Experiment 4	2.3	3.7	8.4	10.5	21	39.2
Experiment 5	0.8	1.4	3.6	6.3	21.6	41.5
Deepest penetration, inches	4	4.2	8.4	10.5	21.6	42
Critical depths, inches	3.5	4.25	7.0	11.5	21.5	42

The following formula is suggested for calculating the critical depth of any grading of sand:

$$C = \frac{100}{w_1\frac{1}{c_1} + w_2\frac{1}{c_2} + w_3\frac{1}{c_3} + w_4\frac{1}{c_4} + w_5\frac{1}{c_5} + w_6\frac{1}{c_6}}$$

wherein C is the critical depth, in inches, of the sand under consideration, c_1, c_2, c_3, c_4, c_5, and c_6 are the critical depths, in inches, and w_1, w_2, w_3, w_4, w_5, and w_6 are the percentages by weight of the grades 1, 2, 3, 4, 5, and 6 in a sample as ascertained by a sieve analysis.

The derivation of the formula is based on the assumptions that the depths of the grades are proportional to their weights, that the filtering ability of any grade is the same at all depths, and that after a back-wash the filter bed is well stratified.

Substituting the values of C tentatively established, the formula becomes:

$$C = \frac{100}{.29w_1 + .23w_2 + .14w_3 + .087w_4 + .046w_5 + .0247w_6}$$

In designing filter beds from the above formula it would, of course, be desirable to increase the depth to allow a factor of safety. The necessary supporting medium aids in that respect.

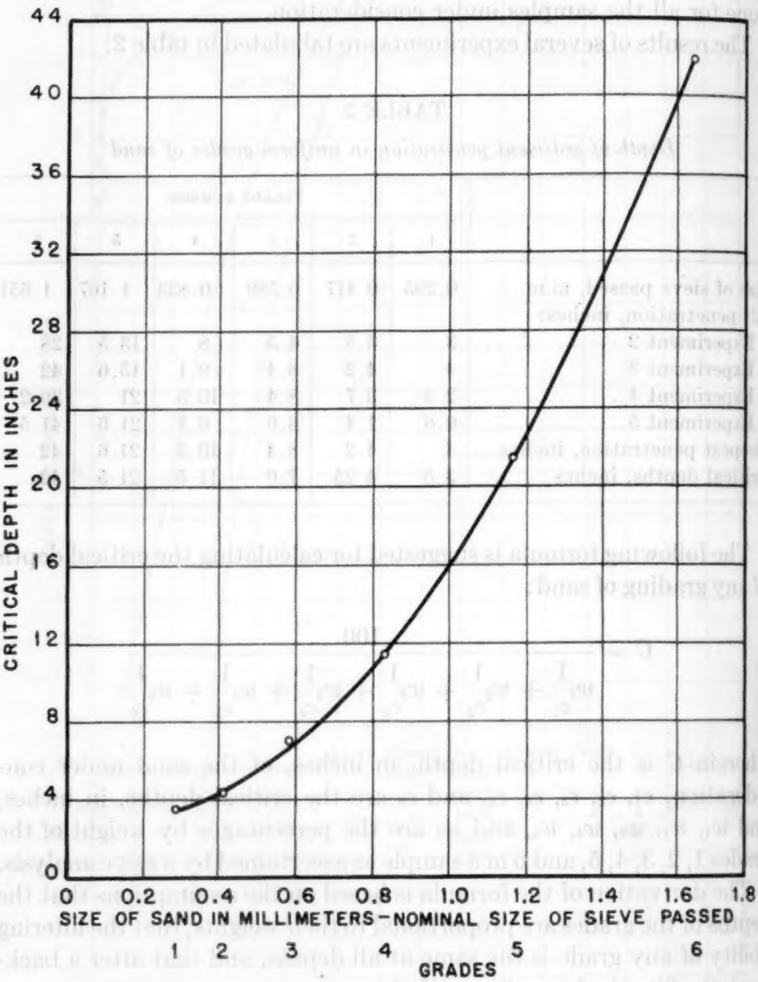

FIG. 6. CRITICAL DEPTHS OF UNIFORM GRADES OF SAND

Filtration

The information in table 3 shows the hours of service of the six grades for several runs.

TABLE 3

Filter run data

PERIOD OF RUN	TEMP. APPLIED WATER	TURBIDITY RAW WATER	ALUM GRAINS PER IMP. GAL.	LENGTH OF RUN—HOURS GRADE NUMBERS					
				1	2	3	4	5	6
1933									
August 10–12	56.5	21	1.5	9½	5	8½	18	30	43½
August 21–23	56	4.6	0.5	10	11½	14½	21	42	54
December 8–21	38.3	9.2	1.3	5	5	21	22	48	62
1934									
February 1–8	35.6	4.3	0.3	24	52	73	80	104	164
April 8–12	37	10	0.7	12¼	14¾	19	26½	37½	91¼
April 30–May 6	40	4	0.5	9	20½	34	54	92	155
May 16–25	43	2.6	0.5	7½	13	35	56	154	217
June 8–14	45	2	0.5	5½	7	18	30	54	141
Average length of run				10	16	28	38	70	116

Note. In the first run the filter containing sand grade no. 1 was not started until the second day and this accounts for its hours of service being greater than those of grades 2 and 3.

Sand rise

The purpose of the sand rise experiments was to ascertain if sand rise curves for uniform grades of sand can be used to calculate the sand rise of any special grading. Accordingly, grade no. 2 was placed in a filter tube to a height of 20 inches on a previously prepared thin layer of fine lead shot, and sand rise experiments were preformed. This procedure was carried out in turn for grades nos. 3, 4, 5 and 6, and for a mixture of the grades. The mixture was made up by placing grade no. 6 into the filter tube to a height of 4 inches. Grade no. 5 was then placed on top of grade no. 6 to a height of 4 inches and so on until five grades had been placed giving a column of sand 20 inches high. In all cases when putting sand into the filter tubes it was consolidated hydraulically by allowing water to rise slowly in the tube and then by drawing water off through the effluent valve at the same rate as when filtering.

Results plotted in figure 8 show that up to a water rise of 40 inches per minute the sand rise for the different grades of sand is proportional to the water rise. The sand rise curve of grade no. 2 appears to be a straight line and the 50 percent expansion curve of water rise

plotted against size of sand grains is almost a straight line. The sand rise curve of the mixture is reasonably close to the curve obtained

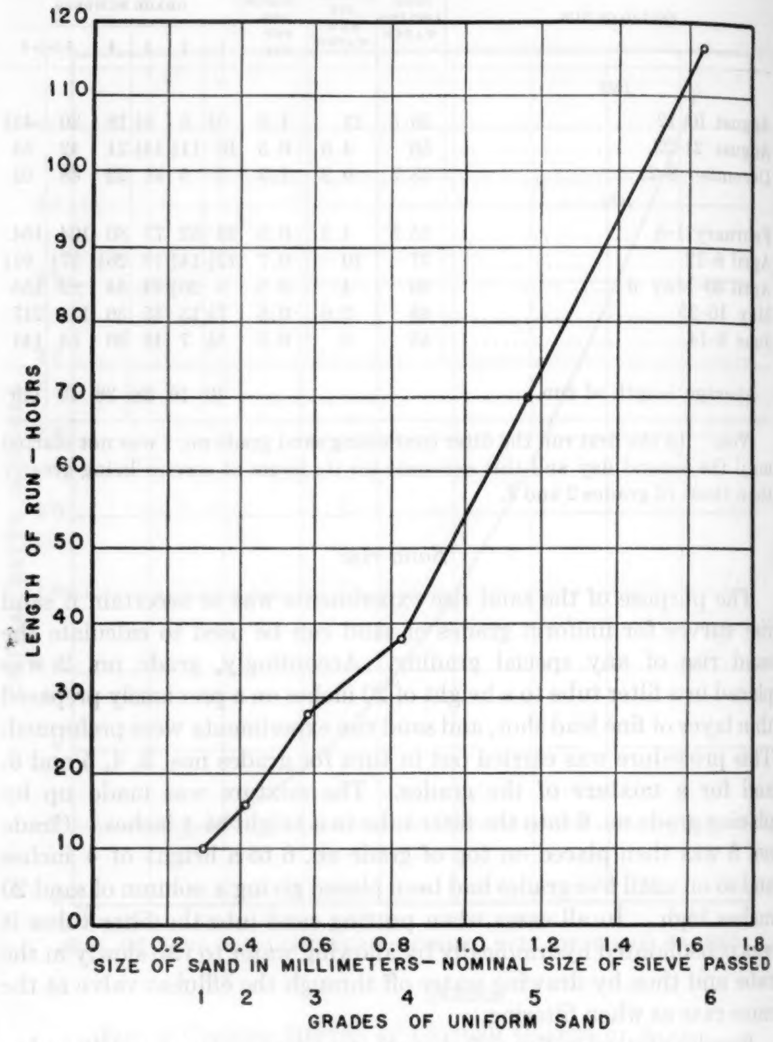

Fig. 7. Length of Run

by calculating the values of sand rise from the formula for any mixture of the grades.

TABLE 4

Length of run

RUN NUMBER	PERIOD OF RUN	ALUM GRAINS PER IMP. GALLON	AVERAGE TURBIDITY		LENGTH OF RUN—HOURS FILTER NUMBERS							
			Raw	Applied	1	2	3	4	5	6	7	8
	1932											
Series 1												
7	July 4–18	1½	5.2	3.9	23.3	33	43.5	54	105	140	186	323.6
8	July 27–August 4	1	3.1	1.5	21	25.8	38.5	46.7	71.5	97	161.2	198.5
9	August 11–21	¾	2.5	1.5	3	5	9	22	75	112	180	232
10	September 2–11	1½	3.3	1.7	19.5	24.6	38.5	55.5	87.5	98.3	127.5	218.5
11	September 29–October 6	½	1.6	1.1	16.5	24.2	29.4	36.6	59.5	68.5	95.5	178.2
13	November 8–10	½	69.5	12.8	11.5	22.5	32.5	48.5	48.5	48.5	44.5	40.5
14	December 7–12	½	18.4	3	14	17	26.2	37.2	82.5	117	117	73
	1933											
Series 2												
1	March 7–11	1	14.3	2.5	22.5	35	55	75.5	98.5	98.5	78.5	78.5
2	March 14–18	1	22.6	2.8	34	42	58	70	90	70	70	46
3	March 30–April 3	¾	17.3	4.6	14	23	36	50	96	96	24	20
4	April 11–15	1	11.4	3.9	24	34	54	65	78	78	50	30
Series 3												
1	May 7–9	1	8.2	8.4	7.5	15.5	25.5	30.5	44.5	44.5		
Average					17.6	25.1	37.2	49.3	78	89	94.5	121.6

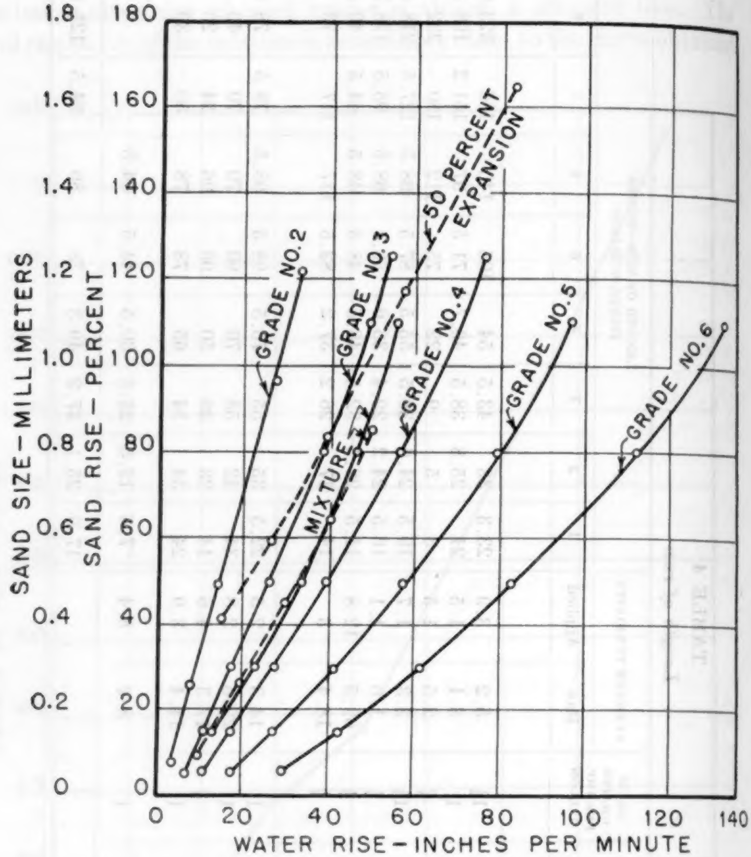

FIG. 8. SAND RISE CURVES OF UNIFORM GRADES

The 50 percent expansion curve is derived by plotting the water rise for each grade, required to give this expansion, against sand size. The "mixture" consists of equal parts of the grades by height in the filter tube. The full line curve is plotted from experimental data, the broken line curve from calculated data.

It is believed that the sand rise of any grading of sand may be calculated with reasonable accuracy from the following formula:

$$S_p = \frac{w_1s_1 + w_2s_2 + w_3s_3 + w_4s_4 + w_5s_5 + w_6s_6 + \text{etc.}}{100}$$

wherein for any stated water rise, S_p is the percentage sand rise of the sand under consideration, $s_1, s_2, s_3, \ldots$ are the percentage sand rises read from the curve for the grades 1, 2, 3, ... respectively, and $w_1, w_2, w_3, \ldots$ are the percentages, by weight, of the grades as ascertained from a sieve analysis of the sample.

The derivation of this formula is based on the assumption that the sand under consideration will separate hydraulically into the grades adopted for these experiments.

ACKNOWLEDGMENTS

The Toronto Filtration Plant is a branch of the Water Supply Section of the Department of Works. Mr. R. C. Harris is Commissioner of Works, Mr. G. G. Powell, Deputy City Engineer, and Mr. A. U. Sanderson, Engineer of Water Supply.

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TREATMENT OF WATER TO PREVENT CORROSION

By John R. Baylis
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Prior to the time when no effort was being made to reduce corrosion in public water supplies, the corrosiveness of the water varied greatly for different cities. The water in some of the supplies was known to be acid, yet in the vast majority of supplies it was alkaline, according to the customary test for alkalinity. There was no very good explanation as to why some of these waters corroded the pipes very much more readily than others. In giving this matter consideration in 1919 and 1920, the equilibriums of certain substances in solution were studied. Where the water was fairly non-corrosive to iron pipes it was found that it was saturated or nearly saturated with calcium carbonate, and where it was corrosive the water was not saturated with this compound. It was only one or two years prior to this that chemists began to give consideration to the hydrogen ion concentration of water and the value of the test had not been demonstrated. This test later proved of considerable value in quickly determining the saturation equilibrium of calcium carbonate and has become a tool which the chemist can use to aid in determining if the water is at the desired equilibrium.

A very important fact about the amount of soluble iron which will exist in water was established about 10 years ago, and that is, practically no soluble iron will exist in water saturated with calcium carbonate, except perhaps momentarily where a fresh iron surface is exposed to water. This has been explained in previous publications (1). By taking lathe turnings of the iron from iron pipes so as to have a very large fresh metal surface, and submerging in a vessel filled with water, sealing so that no air could gain access, and allowing the water and lathe turnings to stand for certain periods, no appreciable amount of iron in solution was found when the water was saturated with calcium carbonate. A number of such experiments thoroughly demonstrated this to be the fact. When the water contained considerable calcium bicarbonate, and yet due to the presence of considerable carbon dioxide it was not saturated with

calcium carbonate, the equilibrium would be changed by corroding iron in the direction of producing saturation by reducing the CO_2 of the water. The carbon dioxide united with the iron, and if sufficient time was allowed, an equilibrium would be established in which the water was saturated or supersaturated with calcium carbonate. Even though there may have been considerable corrosion of the iron to establish the equilibrium, the water was found to be almost free from soluble iron after a short period. Usually less than 0.1 p.p.m. of iron in solution would be present. The low solubility of iron in water saturated with calcium carbonate demonstrates that if the water is kept saturated with this compound the products of corrosion will be precipitated almost as soon as they are formed.

EARLY USES OF ALKALI TO REDUCE CORROSION

It is not known who first used an alkali to reduce the corrosiveness of water. The writer (2) used lime primarily for this purpose as early as 1915, but there was some use of the treatment earlier than this. The chief use of alkalies in water treatment up to about 1925 was to bring about good precipitation of the coagulation, and not much consideration was given to its value in reducing corrosion. The first attempt to reduce corrosion on a large scale by treatment of the water with an alkali was at Baltimore in 1920 (3). Shortly aftewards there was mention in the literature of a few other places which began the use of an alkali to reduce corrosion. The work at Baltimore did not at first attract much attention, and it was not until about 1926, when additional information was published, that treatment of corrosive waters began to make headway. Since then progress has been quite rapid and a large percentage of the corrosive waters are now being treated.

PROTECTIVE FILM ESSENTIAL TO PREVENT CORROSION

It should be evident from the hypothesis of corrosion that it is not possible to treat the water in a public water supply in such a manner that no corrosion will take place when a fresh iron surface is exposed to the water. The only means of preventing corrosion is by protecting the iron in some manner. Practically all water pipes have a protective coating applied by the manufacturer. The coatings most commonly used are not permanent unless they become protected by another coating built up from products in the water. Pipes usually are not installed for a few years' use and it is not possible, except for

very large ones, to recoat the pipes with their former coating without removing them from the ground. For the average city, it might be said that none of the inside pipe surface can be repainted, due to the small size of the pipes.

Where the water is corrosive to iron or galvanized iron it should be treated to make it non-corrosive if it is desired to avoid the losses due to corrosion. Such losses frequently are very much more than just the replacement of metal in which holes have appeared. Pitting and tuberculation will greatly reduce the carrying capacity of the pipes. The problem of adequately protecting iron water pipes becomes one of producing conditions which will gradually form an impervious coating on the inside of the pipes in addition to the coating which is applied by the manufacturer. The water should not be treated, except possibly for short periods, in a manner which will form a coating rapidly, because if such treatment was continued the carrying capacity of the pipes soon would be reduced by the coating becoming thicker.

The one responsible for the treatment should have a very good idea of the point at which no coating forms and the equilibrium necessary to gradually build up a coating. This will vary considerably in different waters, and it is not possible to determine without trial the exact treatment. Occasional observations should be made on the inside of pipes removed for repairs or changes to see just what is taking place. In this manner a fairly good idea of the thickness and effectiveness of the coating built up from products in the water may be obtained. It is not advisable to wait until the protective coatings applied by the manufacturer begin to fail before the water is treated. These coatings should not be allowed to fail, for once the water gains access to the iron surface, pits with overlying tubercles begin to form. Even though a great deal of iron may not be eaten away as a result of the formation of pits, the tubercles as has been stated, greatly increase friction losses in the pipe.

EQUILIBRIUM WHICH SHOULD BE USED

The most desirable equilibrium is to have the water saturated with calcium carbonate, and for short periods of time it should be slightly supersaturated. It is evident that it would be impossible to keep the water exactly saturated with calcium carbonate all the time, and to be on the safe side it is better to aim at a slight supersaturation for several years after the treatment is started, and then if observations

on the inside of pipes indicate that the coating not only covers the surface but is becoming thicker, that is, over about $\frac{1}{64}$-inch in thickness, the treatment can be reduced to where there is no tendency for it to build up thicker. It is believed if one tries to make the water just saturated with calcium carbonate that the fluctuations in the application of the alkali will be such that at times the water will have a tendency to deposit calcium carbonate, owing to a slight supersaturation, and at other times it will have a tendency to dissolve calcium carbonate, when it is below the saturation point. The net result very likely will be no material increase or decrease in the thickness of the coating.

As there are several alkaline compounds in most waters, it is not possible to give a method for computing the equilibrium. The alkaline substances most commonly encountered are calcium carbonate, magnesium carbonate, and frequently sodium carbonate. These compounds usually exist largely as bicarbonate instead of monocarbonates, depending upon the carbon dioxide present. Figure 1 gives curves showing the approximate saturation equilibriums of calcium carbonate and magnesium carbonate. pH is used for one of the ordinates and the concentration of the alkali for the other ordinate. The figures actually given for the alkali concentration are cubic centimeters of N/50 H_2SO_4 per 100 cc. of the water required to neutralize the alkali. The cubic centimeters of acid used multiplied by 10 gives the alkalinity, which, when the alkali is calcium carbonate, is the p.p.m. of calcium carbonate. If the alkali is sodium carbonate or magnesium carbonate the p.p.m. will vary somewhat from that of calcium carbonate. Sodium carbonate is so soluble there is no need of giving its saturation equilibrium, for it never occurs in water to the saturation point.

It will be noted from the curves that there is considerable difference between the saturation equilibrium of calcium carbonate and magnesium carbonate. It is doubtful if the water of a public supply will ever be saturated with magnesium carbonate, and certainly it is not desirable to turn water into a distribution system so alkaline that magnesium in any form will be precipitated on the surface of the pipes. The chief significance of the presence of magnesium and sodium carbonates in the water is to vary the equilibrium of calcium carbonate, especially when the pH and alkalinity determinations are used for obtaining the saturation point. This effect may be illustrated by the broken line in figure 1, which is the approximate

equilibrium of calcium carbonate when the water contains 10 p.p.m. of Mg as magnesium carbonate.

The curve for calcium carbonate shows the pH at saturation equilibrium to be 7.6 for 100 p.p.m. of calcium carbonate. When there is a mixture of calcium and 10 p.p.m. of magnesium, the pH at saturation equilibrium of calcium carbonate is about 7.9 for an alkalinity of 100. Increasing the magnesium increases the pH at saturation equilibrium, and decreasing it decreases the pH. This is also the case when sodium is present as sodium carbonate, and the effect probably is still more pronounced, although accurate tests

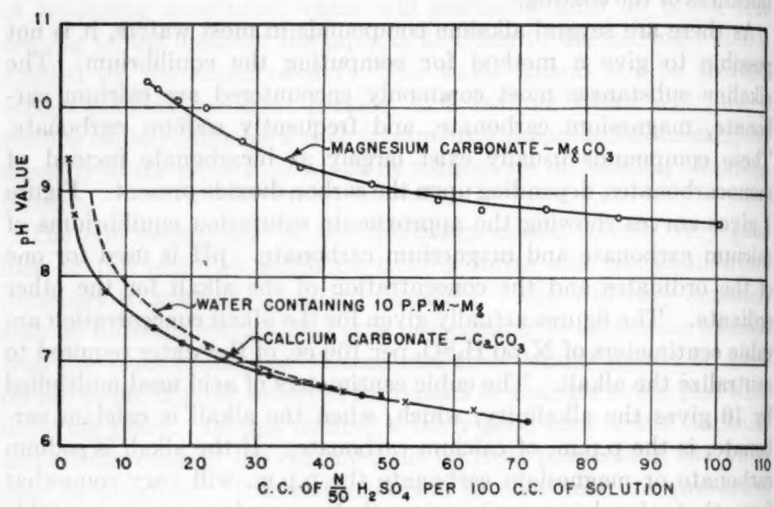

FIG. 1

have not been made to determine if this is true. Sodium carbonate or hydroxide will replace the calcium which is in combination with sulfates and chlorides and such sodium as unites with these substances exists as a neutral salt and has little effect upon the saturation of calcium carbonate unless present in large amounts. The calcium carbonate is, of course, increased in proportion to the amount of sodium which replaces the calcium in combination with the sulfates and chlorides.

At the present time the only practical way of determining if the water is above or below the saturation point of calcium carbonate is to determine if it will dissolve or precipitate calcium carbonate when placed in contact with the powdered material. Procedure for making

this determination is given in another paragraph. It should be evident from the curves that the concentration of calcium carbonate at saturation equilibrium varies widely for different waters. If no other alkaline substance is present in appreciable quantities, the desired equilibrium can be obtained from the curve, but there are very few waters in which it is safe to use the curve. The only practical thing to do is to determine the equilibrium of the particular water which is being treated, and establish a curve for the saturation point of calcium carbonate.

LIME USED MOST EXTENSIVELY

Lime is used very much more extensively than any other substance for reducing the corrosiveness of water. Where the amount of calcium carbonate present is less than about 30 p.p.m., the use of lime is almost essential, if fairly good reduction of the corrosiveness is desired. This is due to the difficulty in producing saturation of the calcium carbonate by the use of the sodium alkalies. Where the concentration of calcium carbonate after the treatment is more than 30 p.p.m., either lime or soda may be used, although the cost of the lime treatment to the water department will be very much less than for soda.

Hopkins (4) made a comparison of lime and soda for treating the Baltimore water, and found that 8 to 10 p.p.m. of caustic soda, or 20 to 30 p.p.m. of soda ash were required to be equivalent to 6.7 p.p.m. of lime. The cost per million gallons for treating the water to obtain a pH of about 8.2 would be approximately $0.24 for lime, $2.79 for sodium hydroxide and $4.84 for sodium carbonate. It is assumed that this was based upon the market prices of the materials in 1933. This does not mean that lime is so much more economical than the other compounds to the water consumer, for lime hardens the water and increases the soap consumption. It also increases the cost of treating the water in certain industrial plants where it has to be again treated before use. As the cost of the treatment cannot be passed on directly to the consumer without increasing the water rate correspondingly, most water departments prefer to use the cheaper treatment and let the consumer pay the difference by having to use more soap, etc.

WHERE TO APPLY ALKALI

In plants using aluminum sulfate to coagulate the water, and where there is sufficient natural alkalinity to produce chemical reac-

tion with the aluminum sulfate, it almost invariably is better to apply the alkali for preventing corrosion after the coagulant has been added. In many instances the alkali is being applied to the filtered water. This is the best point of application if no trouble results from adding it here. Lime produces a certain amount of sludge which is composed of some lime and other impurities in the lime. If the lime is added to the water as it goes from the filters to the clear water reservoir so that it receives thorough mixing before reaching the reservoir, most of the available lime will go into solution. Then if the period of standing in the clear water reservoir is more than about one hour, not much of the lime sludge will be drawn into the distribution system. Where the clear water reservoir can be flushed out occasionally, the accumulation of sediment from the lime treatment will not be very objectionable. Fortunately the insoluble matter is fairly heavy and it does not require a very long period of standing for it to settle to the bottom. Lime is being added to the filtered water of a number of supplies where it does not receive very good mixing with the water. This results in more lime use and in producing more sediment in the clear water reservoir. It is believed that some of the plants could construct some kind of a mixing arrangement and obtain much more satisfactory results.

Lime sometimes is added to the water just before it goes to the filters when aluminum sulfate is used for the coagulant. This may result in throwing some of the aluminum hydroxide into solution, but where there is very good sedimentation in the plant, not very much of the aluminum precipitate goes to the filters. One advantage in applying the lime at this point is that it is mixed thoroughly with the water and all of the insoluble material is filtered out. This advantage somewhat offsets the disadvantage of interfering with the precipitate. It is difficult to state which point is preferable. There may be a few instances where lime is applied in the mixing basin after the flocculation has been formed. This perhaps is better than applying lime in advance of the aluminum sulfate, but it interferes with the coagulation so much it is not believed desirable to apply it at this point, unless it is the only point in the plant where it can be applied after the coagulant. There are a few instances where the lime is applied to the suction of the high pressure pumps. This may result in clogging the water pipes near the pumps and may eventually cause serious stoppage of the pipes. This, however, may be far less serious than to allow the water to corrode the pipes. Such a point of

application should be regarded as temporary until arrangements can be made for applying it elsewhere.

When iron is used to coagulate the water, the lime may be applied before or after the application of the iron. If it is not needed to assist in bringing about proper chemical reactions it may be applied at most any suitable point in the plant. There is no interference by lime with coagulation of the water when iron is used, except perhaps in unusual cases. Less trouble usually will result by applying the lime in the mixing basin than at any point later in the treatment process.

When sodium hydroxide or sodium carbonate is used for the correction treatment it may be applied at almost any point in the plant, although the most desirable point when aluminum sulfate is the coagulant will be in the filtered water. There is very little insoluble material in the soda compounds and there is no objection to applying either of them to the water as it goes to the pumps. It will interfere with the aluminum hydroxide coagulation the same as lime and should not be applied in the mixing basin unless there is no other point available.

DETERMINING THE SATURATION EQUILIBRIUM OF CALCIUM CARBONATE

It has been stated that due to the presence of other alkaline compounds in water the only way of determining the exact saturation point of calcium carbonate in natural waters is by tests. It is a test which will not have to be repeated daily, but only occasionally, unless the water varies widely in soluble constituents. Use fairly insoluble glassware, such as flint or pyrex glass. A one-liter glass stoppered bottle is a convenient size. Add about 200 grams of finely pulverized calcium carbonate to the bottle and wash with water similar to that which is to be tested. After agitating the water and calcium carbonate by tilting the bottle backward and forward a few minutes, allow it to stand a few minutes until nearly all of the calcium carbonate settles to the bottom. Pour off the supernatant liquid and repeat the process two or three times. Then add water from the same source as that to be tested and allow to stand over night in contact with the calcium carbonate. It is better to add the water in the early part of the day and agitate frequently during the day. The calcium carbonate is then ready to be used for testing.

Pour off as much of the water as possible and add the water to be tested to the bottle, filling it to the top so that there will be no air

space or at most only a small bubble. Mix the calcium carbonate and water thoroughly at frequent intervals for at least 24 hours, or if the mixing is done only during the day time, mix for at least two days and allow to stand over night before taking a sample for testing. Where a shaking machine is available which will keep the calcium carbonate mixed thoroughly with the water, equilibriums probably can be established within 6 to 8 hours, although it is advisable to agitate longer. After it is thought that equilibrium has been established, it is best to let the samples stand over night before testing.

When the stopper is removed for obtaining a portion of the water for testing, withdraw some of the water from near the center of the bottle with a pipette for making the pH test, without allowing it to come in contact with the air more than is necessary. Make the pH test as quickly as possible before the water has time to absorb CO_2 from the air. When withdrawn from near the center of the bottle it should be perfectly clear after standing over night. If monocarbonate alkalinity is present, withdraw enough of the clear liquid for making the test. The water for making the total alkalinity test should be filtered through paper, but that for making the monocarbonate alkalinity and pH tests should not be filtered. To filter for the total alkalinity test use a filter paper 12 to 15 cm. in diameter and wash it thoroughly before using. Discard at least 100 cc. of the first water filtered and then filter enough for making the test.

The pH and alkalinity of the water should be determined before being placed in contact with the calcium carbonate. If the alkalinity of the water is increased by being in contact with the powder, it shows that some calcium carbonate has been dissolved and that the water is corrosive to calcium carbonate. If the alkalinity is reduced, calcium carbonate has precipitated and the water was supersaturated with calcium carbonate. No change indicates that it is at equilibrium. There should be no appreciable change in the pH if the water is at equilibrium. If the water is found to be less than saturated or supersaturated it should be treated to change in the direction of the saturation point. Usually it does not require more than two or three trials to determine the exact equilibrium. Where it is essential to hasten the work, several samples, in which the pH and alkalinity have been varied, can be tested simultaneously. The chemist soon learns how to determine the equilibrium point without very great difficulty. The calcium carbonate powder may be used for a number of tests, but the bottle should be kept full of water similar to that to be tested when not being used in a test.

CHEMISTRY OF THE TREATMENT

Almost invariably the acidity of the water of our public supplies is caused by carbon dioxide, and usually there is some free carbonic acid in the water. The dividing line between no free carbonic acid and free carbonic acid is generally taken at a pH of approximately 8.1. It may be that this is not the exact dividing line, but it is so near the error is very little. It happens to be at a pH which gives a faint pink color with phenolphthalein, and this indicator is almost invariably used for determining the free CO_2, or the amount of monocarbonate alkalinity. When an alkali is added to the water to the extent that it produces a pH of 8.1 or less, the chemical reaction is to form bicarbonate alkalinity, but when more than this amount is added, some monocarbonate alkalinity is formed and the solution may contain both mono- and bicarbonate alkalinity. The chemical reactions involved in the use of lime, sodium hydroxide and sodium carbonate are as follows:

(1) $CaO + H_2O = Ca(OH)_2$
(Calcium oxide) (Calcium hydroxide)

(2) $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$
(Calcium hydroxide) (Calcium carbonate)

or

(3) $Ca(OH)_2 + 2CO_2 = CaH_2(CO_3)_2$
(Calcium hydroxide) (Calcium bicarbonate)

One p.p.m. of CO_2 requires 0.6375 p.p.m. of CaO to convert the CO_2 and CaO to calcium bicarbonate.

0.6375 p.p.m. of CaO is equivalent to 1.138 p.p.m. of hardness expressed as $CaCO_3$, therefore the conversion of one p.p.m. of CO_2 to calcium bicarbonate increases the hardness 1.138 p.p.m.

(4) $CaH_2(CO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$
(Calcium bicarbonate) (Calcium hydroxide) (Calcium carbonate)

One p.p.m. of monocarbonate alkalinity requires 0.280 p.p.m. of CaO to produce this compound from calcium bicarbonate. This amount of CaO produces 0.50 p.p.m. of hardness.

(5) $2NaOH + CO_2 = Na_2CO_3 + H_2O$
(Sodium hydroxide) (Sodium carbonate)

or

(6) $NaOH + CO_2 = NaHCO_3$
(Sodium hydroxide) (Sodium bicarbonate)

$$(7) \quad \underset{\text{(Sodium bicarbonate)}}{NaHCO_3} + \underset{\text{(Sodium hydroxide)}}{NaOH} = \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O$$

One p.p.m. of CO_2 requires 0.910 p.p.m. of NaOH to convert the CO_2 and NaOH to sodium bicarbonate. There is no increase in hardness of the water.

$$(8) \quad \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + CO_2 + H_2O = \underset{\text{(Sodium bicarbonate)}}{2NaHCO_3}$$

One p.p.m. of CO_2 requires 2.411 p.p.m. of Na_2CO_3 to convert the CO_2 and Na_2CO_3 to sodium bicarbonate.

Almost invariably the water of our public supplies contains sulfates and chlorides. Usually some of the calcium is in combination with these substances. When this is the case, and sodium hydroxide or sodium carbonate is added to the water, it will replace calcium in combination with these substances. 0.801 p.p.m. of sodium hydroxide and 1.061 p.p.m. of sodium carbonate are equivalent to 1 p.p.m. of calcium carbonate; that is, if calcium sulfate is present and the water is treated with sodium hydroxide the addition of 0.801 p.p.m. of sodium hydroxide will cause the formation of 1 p.p.m. of calcium carbonate. This is assuming that the sodium replaces the calcium, and also that the CO_2 necessary to combine with the calcium is present in the water. Water usually contains some magnesium and the first reaction of the sodium may be to replace magnesium.

COST OF TREATING WATER TO PREVENT CORROSION

It is not difficult to compute the approximate amount of chemicals necessary to add to water to produce saturation of calcium carbonate if the pH and alkali concentration at equilibrium are known. The chemical cost, however, is not the only cost when lime is used, because the water is hardened some by the lime. This requires the use of more soap in the homes, and also there is some additional expense to certain industries which have to soften the water before use. It is difficult to estimate this cost very accurately. Hudson and Buswell (5) give the per capita soap consumption in several cities where the water varies considerably in hardness. Their figures indicate that 1 p.p.m. of hardness costs nearly one cent per capita per year. It is believed for the average city that one cent per capita per year for each part per million of hardness is a fair figure for the total cost due to hardness of the water. There may be evidence in some cities that the cost will be more and others that it will be less. It probably will be impossible to determine this cost exactly.

When one cent per capita per year for each part per million of

hardness is used to compare the cost of hardness in a city which has a hardness of 50 p.p.m. with another which has 200 p.p.m., it indicates that the excess hardness is costing $27.00 per million gallons to the citizens of the hard water city over what it is costing in the low hardness city. The computation is based upon a per capita consumption of 150 gallons per day. Should the per capita consumption be less the cost per million gallon will be more. Reduction of the costs due to hardness of $27.00 per million gallons for 150 p.p.m. reduction seems like a reasonable figure, but should it be considerably more, treatment of water to prevent corrosion would still be economical.

TABLE 1

Cost of converting CO_2 to bicarbonate

TREATMENT	COMMERCIAL MATERIAL TO COMBINE WITH ONE P.P.M. CO_2	COST PER POUND OF COMMERCIAL MATERIAL	COST PER MILLION GALLONS OF CONVERTING ONE P.P.M. CO_2 TO BICARBONATE	HARDNESS INCREASE TO NEUTRALIZE ONE P.P.M. OF CO_2	TOTAL COST† PER MILLION GALLONS TO REDUCE ONE P.P.M. OF CO_2 TO BICARBONATE
	p.p.m.	*dollars*	*dollars*	*p.p.m.*	*dollars*
Lime	0.75*	0.005	0.032	1.138	0.242
Sodium hydroxide	0.910	0.025	0.189	0.000	0.189
Soda ash	2.411	0.012	0.241	0.000	0.241

* Based upon 85 percent water soluble CaO.

† Based upon a per capita cost of 1 cent per person per year for each p.p.m. of hardness, and upon an average water consumption of 150 gallons per capita per day.

Table 1 compares the cost of converting the free CO_2 in water to bicarbonates by use of lime, sodium hydroxide and soda ash. This is the cost of increasing the pH to 8.1, which may be sufficient for many waters having a calcium carbonate concentration of 50 p.p.m. or more. Almost invariably some magnesium is present to vary the pH and the exact equilibrium for a definite concentration of calcium carbonate cannot be stated. The cost per million gallons given in the last column of table 1 is based upon a per capita consumption of 150 gallons of water daily. If the market prices of the materials are as given in table 1 the cheapest material to use is sodium hydroxide. This, however, may not be the case, for the use of sodium requires a higher pH to produce saturation equilibrium for a given alkalinity. When this is taken into consideration the cost of sodium hydroxide and lime will be approximately the same.

It has been stated that lime should be used for all waters where, after the treatment, there will be less than 30 p.p.m. of calcium carbonate. As lime is much cheaper to the water works and there is no economy in the use of soda compounds, it is believed that lime will be used in most instances for higher concentrations. The writer has no definite information on the costs of lime and soda for fairly hard waters and it is possible that the figures may be more favorable to the soda compounds in such cases.

Caution should be given that one cannot take the figures given in table 1 to estimate the cost of treating water to prevent corrosion for all cities. This is the cost of treating the water to a certain definite pH. Where the water is soft, instead of treating to a pH of 8.1, it may be necessary to treat to pH of 8.5 or 9.0. Assume that the water contains 5 p.p.m. of free CO_2, and that it is necessary to have a monocarbonate alkalinity of 10 p.p.m. to produce the saturation point of calcium carbonate. The amount of lime required to combine with the free CO_2 can be computed by chemical reaction formula No. 3, where the calcium hydroxide is converted to calcium bicarbonate. This figures 3.19 p.p.m. of CaO, which is equivalent to 5.69 p.p.m. of hardness. If 85 percent of the lime is water soluble, 3.75 p.p.m. of commercial CaO would be required to use up the free CO_2 to form calcium bicarbonate. Chemical reaction No. 4 shows that 0.280 p.p.m. of CaO is required to produce one p.p.m. of monocarbonate from the bicarbonate. Ten p.p.m. of monocarbonate alkalinity would require 2.80 p.p.m. of CaO, or 3.29 p.p.m. of the commercial material if it contains 85 percent water soluble CaO. This would make a total of 7.04 p.p.m. of the commercial material to produce the desired equilibrium.

The same procedure can be used for computing the amount of sodium hydroxide or sodium carbonate. It might be well again to caution that a higher monocarbonate alkalinity will be required for the sodium compounds than for calcium to produce the saturation point of calcium carbonate. It has been stated that the exact equilibrium has to be determined by experiments.

There are not many water supplies where it will be necessary to harden more than 12 to 15 p.p.m., unless the free CO_2 is high, and the average probably will not exceed 10 p.p.m. Assuming that this is the average, it will require 5.61 p.p.m. of CaO or about 6.6 p.p.m. of commercial calcium oxide. This is 54 pounds of lime per million gallons of water, which, if it costs 0.5 cent per pound, will be $0.27. Cer-

tainly this is a modest sum and represents a per capita yearly cost of only about 1.5 cents for the city of average water consumption. If the lime cost were twice this figure it still would be so low as to be almost insignificant. These figures suggest that it would be economical to aerate the water when the CO_2 is high.

COST OF CORROSIVE WATER

There is no way of even approximating the cost of corrosive water as compared with fairly non-corrosive water. It is many times 1.5 cents per capita per year, and it is in excess of $0.25 per capita per year for repairs in homes and other buildings, in addition to the cost to the water department for repairs in the streets. The cost to the water department is not much less.

When we consider the cost of pipe repairs in the street and in buildings, loss of water through leaks caused from corrosion, damage to property from leaks, the necessity for larger pipes where it is known that the carrying capacity will be greatly reduced by the formation of iron rust, fire losses due to inadequate pressure, staining clothes being laundered, staining bath room fixtures, and probably other costs, the total loss resulting from corrosive water is quite a large figure. It is a figure much greater than the cost of the treatment. It is unfortunate that the corrosion losses cannot be determined accurately, for it would show so clearly the advantages of treating the water that few would hesitate to make the expenditure where the water without treatment is corrosive.

SUMMARY

The water in many of our public supplies will cause fairly rapid deterioration of iron pipes unless it is treated with an alkali. The proper equilibrium is to have the water saturated with calcium carbonate.

Lime should be used for treating the water where the concentration of calcium carbonate is less than about 30 p.p.m.

Where the concentration of calcium carbonate is over about 30 p.p.m., either lime or soda may be used, although lime is much cheaper to the water works.

Lime increases the hardness of the water, and when this is taken into consideration the cost of the lime or the soda treatment is approximately the same.

Increasing the hardness of the water one part per million increases

the cost to the consumer approximately one cent per person per year in the city of average water consumption.

Not many water works will need to increase the hardness of the water over 10 p.p.m. to produce non-corrosive water with lime. This amount of lime will cost about 1.5 cents per capita per year to the water works where the per capita consumption is 150 gallons daily. The total yearly cost, when everything (including increased soap used, etc.) is taken into consideration, is approximately 11.5 cents per capita.

There is no way of accurately estimating the saving resulting from reducing the corrosiveness of the water, but it certainly is much more than the total cost of the treatment.

(*Presented before the Wisconsin Section meeting, September 25, 1934.*)

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EFFECTS OF ROAD OILS AND TARS ON PUBLIC WATER SUPPLIES

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In a previous article (1) it has been found that the drainage from tarred roads produced objectionable tastes and odors in water supplies after chlorination. Sample sections of road were treated with varying amounts of primer and retread tar and the section of road washed by distilled water equivalent to 1-inch of rainfall per hour. These washings were tested for tastes, phenols, and mixed cresols. The tests showed that the greatest danger of contamination of water supplies was when a rain occurred within four hours after the application of the primer coat. If a local heavy rain occurred in the vicinity of the road oiling job, there was danger of contamination of surface water supplies. One hour after the application of the primer coat, tastes were noticeable in a 1:2,000,000 dilution.

Data seemed to be lacking on the water soluble compounds of the road paving tars and this paper offers the results of tests made on this subject by the Department of Civil Engineering, West Virginia University, Testing Division of the State Road Commission, and the State Water Commission. The laboratory work was performed by the junior authors.

The purpose of these tests was to investigate the following:

1. The danger of contamination of water supplies from the washings from asphalt roads.

2. To express in terms of a phenol equivalent, the percentage of water soluble, chlorine absorbing compounds present in road tars.

3. To express in terms of phenol equivalent, the percentage of water soluble, chlorine absorbing compounds present in the distillation fractions of the tars. 0° to 170°C.; 170° to 235°C.; 270° to 300°C.
4. The possibilities of their sufficient practical elimination in order to prevent contamination of streams.

ASPHALT ROADS

A series of experimental sections of asphalt roads were built and the gravel treated with asphalt primer and asphalt retread, the treatment consisting of one-third gallon per square yard of primer and two-thirds gallon per square yard of retread. Samples were washed from each set, at the end of 1, 2, 3, 4, 24, 48 and 72 hour periods, with water distilled equivalent to a rainfall of one inch per hour. These washings were collected in glass stoppered volumetric flasks and the odors (hot), and the taste (cold) according to the method recommended by (2). Check determinations were made using distilled water on tastes and odors and no discernible difference in taste and odor could be distinguished between the asphalt washings and distilled water.

To further verify the statement that the washings from asphalt roads will not cause tastes and odors after chlorination, samples were tested for phenols by the Baylis modification of the Gibbs method (3); mixed cresols by the method of Fox and Gage (4); and bromination (5). The results of all of these tests were negative and we concluded that washings from asphalt roads are not detrimental to water supplies.

It has been suggested that the bromination method be used as a qualitative test to determine the presence of tar acids in asphaltic compounds since it was found that asphalt does not have bromine adsorbing properties.

MANUFACTURE OF COAL TAR

There are several different commercial practices in manufacturing coal tars depending on the viscosity of the raw tar, materials available for "cutting-back" or thinning the raw tar, and the viscosity or consistency of the finished coal tar.

If the raw tar is light, having for example, a specific viscosity of 5 and a road tar having a specific viscosity of 13 is desired, it is only necessary to distill off sufficient light oils to give a still residue of the required consistency. This leaves all the by-products in the tar which have a distillation range above the temperature required for

the light oils. A road tar having the same viscosity may be made by distilling off the various oils until a soft pitch is left in the still, removing from the distillate all the by-products desired then adding the neutral and extracted oils to the pitch in the proportions to give a specific viscosity of 13. It is not considered good commercial practice to use the hard pitch left in the still after the manufacture of the heavier creosote oils.

If the raw tar is heavier, having a specific viscosity higher than 13, then lighter tars or tar oils must be added to give a product having a specific viscosity of 13. The lighter tars or tar oils very frequently

TABLE 1

Fractional distillation of coal tar (9, 11)

DISTILLATE	PRINCIPLE CONSTITUENTS OF THE FRACTIONS	DISTILLING TEMPERATURE	OUR TEMPERATURE CUTS
1. Light oil or crude naptha	Benzene and homologues	To 170° or to 210°	To 170°
2. Middle or carbolic oil	Carbolic acid and naphthalene	170°–230° or 210°–240°	170°–235°
3. Heavy, or creosote oil	Naphthalene constituents not usually separated	230°–270° or 240°–270°	235°–270°
4. Anthracene oil	Anthracene	Above 270°	Above 270°
5. Pitch or tar	Residue in the still		

are not coal tars, that is, they are not derived in the process of coking coal, but are derived from the manufacture of gas, etc.

Naturally the heavier the consistency of the road tar, the more of the lighter fractions have been removed until we have a road tar, a semi-solid, which has, on the average, 10 percent distilled off at 300°C. Table 1 gives the fractional distillation of coal tars.

CONSTITUENTS OF COAL TARS, AND THEIR PROPERTIES

One would not expect to find much benzene, toluene or xylene to be present in a road coal tar since these products are too valuable and easily recovered. Such products such as naphthalene and anthracene are not removed unless the market price is sufficient to warrant their

recovery. Of these two latter products, naphthalene is more valuable and more likely to be extracted. By temperature and period regulation during the coking of the coal these two products can be lessened in amount at the same time increasing the phenol yield. The length-

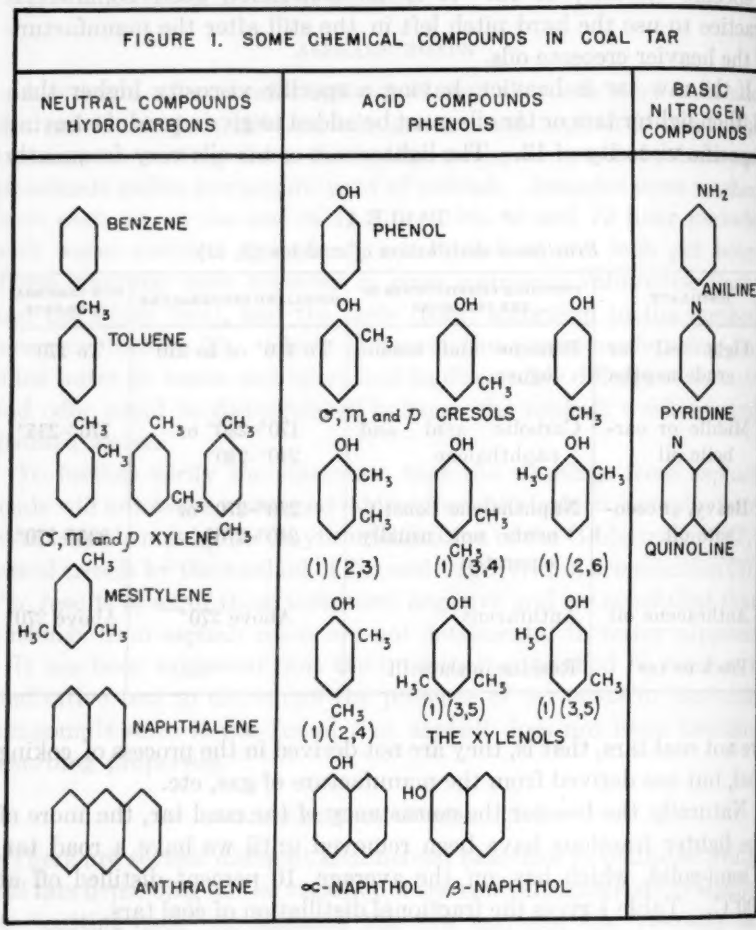

Fig. 1

ening of the coking period with a decrease of temperature has been practised extensively during the recent slump in market prices in order to continue operation without a high yield of coke. The phenols are usually partially extracted; however if there are no markets available they are allowed to remain in the tars.

Due to incomplete commercial extraction of phenols, where the so-called "neutral oils" are added to the heavier tars from the stills in the manufacture of road tars, it is entirely possible to have 3 per cent or more of phenols in the tar.

Chemically, coal tar is a highly complex mixture of many compounds belonging to three classes. These classes are shown in figure 1.

The yield of coal tar in the original distillation of the coke is about 2 to 5 percent and depends upon many physical or mechanical factors, such as temperature and pressure of the distillation, form of still, time, etc. Approximate yields are given in table 2.

TABLE 2

*Yield of compounds in coal tar in percent**

COMPOUNDS	PERCENT
Benzene, toluene, xylene	1.0 – 2.5
Naphthalene	4.0 –10.0
Anthracene	0.25– 2.0
Phenol	0.4 – 0.5
Cresols	2.0 – 3 0
Pyridine and quinoline	0.2 – 0.3
Creosote oil	25.0 –30.0
Pitch or tar	50.0 –60.0

* Tar = 100 percent.

The solubility of the constituents of coal tar are listed in table 3 (15). The more soluble constituents are; phenol, ortho, meta and para cresol, the most of the xylenols, aniline and pyridine.

Cresols, xylenols and naphthols react about like phenol, but there is some question as to the bromo compounds formed in these reactions. For instance, since they are like phenol we would expect the bromine to take the 2, 4, and 6 positions as they do in phenol. However o-cresol has the CH_3 in the 2 position and p-cresol has the CH_3 in the 4 position while only m-cresol has the 2, 4 and 6 positions open for the bromine. It is believed that it is possible for only one or two bromine to enter the ring in the case of o-cresol and p-cresol. Using the same reasoning for xylenols we find that we may expect only one or two bromine to enter the ring. Likewise in the case of the naphthols we may expect as many as five bromine to enter the ring.

Twelve samples of tar were selected, two samples from each of the

six companies now supplying the larger percentage of road tars to the state of West Virginia. Weighed portions of each tar were distilled (6, 7), the following fractions being collected—0° to 170°C., 170° to

TABLE 3

Water solubility of coal tar compounds

COMPOUND	GRAMS SOLUBLE IN 100 CC. OF WATER
Benzene	0.073 at 22°C., 0.11 at 25°C.
Toluene	0.047 at 16°C.
o-xylene	Insoluble
m-xylene	Insoluble
p-xylene	Insoluble
Mesitylene	Insoluble
Naphthalene	0.0030 at 25°C.
Anthracene	Insoluble
Phenanthrene	
Phenol	9.05 at 20°C., ∞ at 67.5°C.
o-cresol	2.51 at 20°C., 5.42 at 100°C.
m-cresol	2.24 at 20°C., 5.57 at 100°C.
p-cresol	1.99 at 20°C., 5.20 at 100°C.
Xylenol (1, 2) (3)	Soluble
Xylenol (1, 2) (4)	Soluble
Xylenol (1, 3) (2)	Slightly soluble hot
Xylenol (1, 4) (4)	Very slightly soluble
Xylenol (1, 3) (5)	Slightly soluble
Xylenol (1, 4) (2)	Soluble
α naphthol	Slightly soluble
β naphthol	0.074 at 25°C.
Aniline	3.538 at 25°C.
Pyridine	∞
Quinoline	6

Benzene and toluene do not react readily with bromine under ordinary conditions.

Xylene reacts slightly with bromine.

Mesitylene reacts very little with bromine.

Both α-, β-naphthalenes react readily with bromine forming α- and β-bromo naphthalene $C_{10}H_7Br_1$ also naphthalene di-bromide $C_{10}H_8Br_2$.

Anthracene requires heat to react with bromine.

Phenanthrene does not react readily with bromine.

Phenol reacts readily with bromine forming 2-4-6-tri-bromo phenol.

235°C., 235° to 270°C., 270° to 300°C., the residue was discarded. The percentage, by weight, of each fraction collected was recorded.

Approximately one gram of each tar and its individual fractions

were accurately weighed, and mixed with one liter of distilled water. It was noted that the higher fractions contained, in some cases, a large amount of solid matter. This substance could be easily melted by placing the container in hot water. This was done in order to obtain a uniform sample. The solid substances were not identified but had the characteristic odor and form of naphthalene. Upon

TABLE 4

Specifications and analyses of tars used in tests

SERIES NO.	SPECIFIC GRAVITY 15.5°C.	WATER	SPECIFIC VISCOSITY ENGLER AT 40°C.	TOTAL BITUMIN SOL. IN CS_2	DISTILLATION TEST ON WATER FREE MATERIAL TOTAL DISTILLATE BY WEIGHT				SOFTENING POINT (R AND B) OF RESIDUE FROM DISTILLATION
					0–170°C.	0–235°C.	0–270°C.	0–300°C.	
		percent		*percent*					°*C.*
Minimum..	1.12		5	88.0					
Maximum..	1.25	2.0	55		7.0	—	37.0	45.0	60
A	1.133	1.5	9	96.7	1.5	13.8	24.5	33.2	50
B	1.165	1.5	48	96.7	0.6	10.3	19.0	27.3	60
C	1.135	1.0	9	96.6	1.1	13.6	24.5	32.6	57
D	1.121	1.5	7	97.7	2.3	12.4	25.2	33.6	32
E	1.120	1.0	6	96.4	1.7	12.6	23.5	32.9	41
F_1	1.148	1.0	8	97.6	1.0	15.5	26.9	35.0	48
F_2	1.152	1.5	10	97.7	1.1	15.0	25.0	32.4	48
G_1	1.148	0.5	10	96.3	1.4	13.6	22.4	30.4	53
G_2	1.150	1.0	10	96.0	0.6	14.0	22.2	29.8	53
H_1	1.151	0.5	8	96.9	0.6	13.5	25.1	32.9	43
H_2	1.156		15	97.7	1.2	9.8	20.6	27.2	51
K_1	1.169		14	95.4	0.1	4.6	16.9	25.1	41
K_2	1.154	1.0	12	96.2	0.5	6.5	16.3	27.4	45
L_1	1.120	1.0	5	95.6	0.6	13.5	26.6	35.6	44
L_2	1.120	0.5	5	97.9	1.7	13.2	26.3	36.1	41
M_1	1.135	1.0	9	96.5	1.5	16.6	26.2	34.2	60
M_2	1.134	1.0	8	95.6	1.8	14.7	25.5	35.1	60

addition of the distilled water to some of the fractions, what seemed to be suspensions were formed. No effort was made to eliminate this condition. The tar had a tendency to form small globules in the dilution water which would cause a slight error in the completeness of extraction. This effect could have been eliminated by the addition of a small amount of alcohol, but this was not done since the natural conditions of extraction by rainfall were adhered to.

TABLE 5

Bromination—Fox and Gage

IDENTIFICATION	FRACTIONS IN TAR BY DISTILLATION	PHENOLICS IN TAR AND INDIVIDUAL FRACTIONS	PHENOLICS IN FRACTION PARTS OF TAR (TAR = 100 PERCENT)	MIXED CRESOLS IN TAR AND INDIVIDUAL FRACTIONS	MIXED CRESOLS IN FRACTION PARTS OF TAR (TAR = 100 PERCENT)
	percent	*percent*	*percent*	*percent*	*percent*
F_1 Tar		9.75		6.55	
0°–170°C.	1.0	17.60	0.18	4.70	0.05
170°–235°C.	14.5	25.70	3.73	8.06	1.17
235°–270°C.	11.4	15.43	1.76	8.00	0.91
270°–300°C.	8.1	13.30	1.07	4.94	0.40
F_2 Tar		5.36		3.19	
0°–170°C.	1.1	26.20	0.29	6.27	0.70
170°–235°C.	13.9	19.20	2.67	12.98	1.81
235°–270°C.	10.0	12.18	1.22	8.75	0.88
270°–300°C.	7.4	7.11	0.53	1.54	0.11
G_1 Tar		9.39		6.06	
0°–170°C.	1.4	38.30	0.57	14.32	0.20
170°–235°C.	12.2	37.90	4.62	29.40	3.58
235°–270°C.	8.8	29.00	2.55	28.90	2.54
270°–300°C.	8.0	8.80	0.71	24.10	1.93
G_2 Tar		10.60		6.39	
0°–170°C.	0.6	57.40	0.34	46.10	0.28
170°–235°C.	13.4	32.90	4.40	23.10	3.09
235°–270°C.	8.3	28.30	2.32	26.90	2.23
270°–300°C.	7.6	13.60	1.03	9.95	0.76
H_1 Tar		7.70		7.62	
0°–170°C.	0.6	35.60	0.21	17.70	0.11
170°–235°C.	12.9	25.50	3.29	18.50	2.38
235°–270°C.	11.6	19.90	2.31	10.12	1.18
270°–300°C.	7.8	18.10	1.43	7.45	0.58
H_2 Tar		8.43		7.11	
0°–170°C.	1.2	20.80	0.25	9.29	0.11
170°–235°C.	8.6	40.70	3.50	33.90	2.92
235°–270°C.	10.8	35.40	3.83	33.60	3.63
270°–300°C.	6.6	18.10	1.20	8.06	0.53
K_1 Tar		6.90		7.20	
0°–170°C.	0.1				
170°–235°C.	4.5	17.62	0.79	7.61	0.34
235°–270°C.	12.3	14.60	1.80	13.45	1.66
270°–300°C.	8.2	7.38	0.61	12.79	1.05

TABLE 5—*Concluded*

IDENTIFICATION	FRACTIONS IN TAR BY DISTILLATION	PHENOLICS IN TAR AND INDIVIDUAL FRACTIONS	PHENOLICS IN FRACTION PARTS OF TAR (TAR = 100 PERCENT)	MIXED CRESOLS IN TAR AND INDIVIDUAL FRACTIONS	MIXED CRESOLS IN FRACTION PARTS OF TAR (TAR = 100 PERCENT)
	percent	*percent*	*percent*	*percent*	*percent*
K_2 Tar		9.76		2.90	
0°–170°C.	0.5	16.20	0.08	16.52	0.08
170°–235°C.	6.0	17.80	1.07	15.42	0.93
235°–270°C.	9.8	18.50	1.81	13.25	1.31
270°–300°C.	11.1	12.50	1.39	8.32	0.92
L_1 Tar		7.06		2.02	
0°–170°C.	0.6	9.69	0.06	15.85	0.09
170°–235°C.	12.9	17.70	2.28	7.87	1.02
235°–270°C.	13.1	16.30	2.14	10.81	1.42
270°–300°C.	9.0	11.70	1.05	11.62	1.05
L_2 Tar		7.35		4.98	
0°–170°C.	1.7	13.75	0.23	9.88	0.17
170°–235°C.	11.5	14.10	1.62	5.98	0.69
235°–270°C.	13.1	15.70	2.06	11.18	1.46
270°–300°C.	9.8	7.35	0.72	9.70	0.95
M_1 Tar		7.91		7.73	
0°–170°C.	1.5	21.80	0.33	15.18	0.23
170°–235°C.	15.1	23.60	3.29	11.00	1.66
235°–270°C.	9.6	33.20	3.18	19.10	1.83
270°–300°C.	8.0	15.40	0.13	4.59	0.37
M_2 Tar		7.83		2.26	
0°–170°C.	1.8	14.60	0.26	28.55	0.52
170°–235°C.	12.9	26.00	3.36	18.49	2.38
235°–270°C.	10.8	19.90	2.15	20.60	2.22
270°–300°C.	9.6	9.35	0.90	9.25	0.89

DETERMINATION OF PHENOLICS BY BROMINATION

The bromination method (5) of determining the phenolics consisted of the liberation of free bromine in a definite amount of the water extracts from the tar and tar fractions. A standard potassium bromate-potassium bromide solution was used. The unreacted bromine was then replaced by iodine upon addition of a potassium iodide solution and the free iodine titrated with a standard sodium thiosulfate solution, thus measuring the amount of bromine adsorbed.

Due to the presence of compounds other than phenol that reacted with bromine, it was necessary to express the total amount of these compounds in terms of a phenol equivalent since there were no methods of distinction. The phenol equivalent is called "percentage phenolics" in this paper. The equivalent was derived from the calculations that 1 ml. of $N/10$ bromine solution is equivalent to 0.001568 grams phenol (carbolic acid). From this factor, a phenol equivalent percentage by weight was calculated for each tar and its fractions. Using these percentages and the distillation percentages a phenol equivalent percentage was calculated for each fraction on the basis that the fractions' tar equaled unity or 100 percent (see table 5).

In order to have a comparison of the amounts of "phenolics" in each tar and its fractions, an average was made showing the relationship (see table 6).

TABLE 6

SAMPLE	AVERAGE PHENOLICS IN THE TARS AND INDIVIDUAL FRACTIONS BY BROMINATION	AVERAGE IN FRACTIONS ON BASES TAR = 100 PERCENT BY BROMINATION	AVERAGE MIXED CRESOLS IN TARS AND INDIVIDUAL FRACTIONS BY GAGE AND FOX	AVERAGE MIXED CRESOLS IN FRACTIONS ON BASES TAR = 100 PERCENT
	percent	*percent*	*percent*	*percent*
Tars	8.17	8.17	5.08	5.08
0°–170°C.	24.72	0.25	17.66	0.23
170°–235°C.	24.89	2.88	16.02	1.83
235°–270°C.	21.53	2.26	14.81	1.77
270°–300°C.	11.89	0.88	9.36	0.79

TABLE 7

Percent variation of results on bromination and Fox and Gage

SAMPLE	PHENOLICS IN FRACTIONS AND TARS BROMINATION	PHENOLICS IN FRACTIONS TARS = 100 PERCENT	MIXED CRESOLS IN TARS AND FRACTIONS FOX AND GAGE	MIXED CRESOLS IN FRACTIONS TAR = 100 PERCENT
	percent	*percent*	*percent*	*percent*
Tar	5.36–10.6	5.36–10.6	2.02– 7.73	2.02–7.73
0°–170°C.	9.76–57.4	0.06– 0.57	4.70–46.10	0.05–0.70
170°–235°C.	14.10–40.70	0.79– 4.62	5.98–33.90	0.34–3.58
235°–270°C.	12.18–35.4	1.22– 3.83	8.00–33.60	0.88–3.63
270°–300°C.	7.11–18.1	0.13– 1.43	1.54–12.79	0.37–1.93

The variation of "phenolics" in tars and their fractions are shown in table 7.

MIXED CRESOLS

Mixed cresols were determined on the various water-tar extracts by the Fox and Gage method (4) to find the relation between the bromination and the colorimetric methods. This method is based on the formation of the azo dyes obtained when the sulphanilic acid is diazotized and reacts with the water extracted tar acids after being rendered alkaline.

A 0.3 ml. sample of the tar extract, diluted to 50 ml. was found to be a satisfactory amount to test. All fractions of the tars gave a distinct test by this method but the amount of mixed cresols calculated from the results, were less, in every case, than the percentage of "total phenolics" as determined by bromination. These comparisons are shown in tables 5 and 6.

DISCUSSION

Although there were two samples of tar from each of the six companies used in both the Bromination and Fox and Gage tests, the results were not identical even when the viscosities of the two samples were the same. It is assumed that in some cases a comparatively long time elapsed between samples and the plant was recovering different amounts of phenol. The quantity of phenol in road tars seems to depend on whether there is an available market for the phenols sufficient to warrant their recovery.

We would expect in the three methods: Baylis method for determining phenols, Fox and Gage method for determining cresols, and Bromination method for total "phenolics" that the last method would give the greatest amount. The fact that the Bromination results are higher is easily explained by the fact that compounds other than cresols and phenols are present.

Chlorine should act the same as bromine and when water is chlorinated, the chloro-compounds formed should be present in the same proportions as the bromo-compounds. The water solubility of the compounds is a distinct factor.

SUMMARY

1. Tests are presented which show that the washings from asphalt roads do not give objectionable tastes and odors upon chlorination.

2. The Bromination method of determining total "phenolics" is offered as a better measure of the probable taste producing properties of tarred road washings.

3. The Bromination method is suggested as a qualitative test for differentiating between tar and asphalt.

4. Detailed results are presented showing the mixed cresols and total "phenolics" present in the fractional distillation of twelve different commercial road tars.

5. The water soluble compounds present in coal tars are presented together with a brief discussion on the manufacture of tar.

CONCLUSIONS

1. Asphalt road washings do not contain any of the so-called "phenolics" and will not give objectionable tastes and odors in road washings after chlorination.

2. All fractional distillations of the tars contain sufficient "phenolics" to cause objectionable tastes and odors in the wash water. Therefore, it does not appear feasible to eliminate some of the fractions by distillation and rejection of the fractions containing the larger percentage of tar acids. However, it seems more practical to form a "cut-back" tar using fractions from which the objectionable tar acids have been eliminated by neutralization or extractions.

3. Road tar specifications should specify a low phenol content. Belgium allows 5 percent. Several of the tars examined were below this specification.

4. Baylis modification of the Gibbs method for determining phenols is not suitable for testing for phenols when an appreciable quantity of tar acids are present.

5. Bromination method gives a more exact measure of the total "phenolics" or taste producing compounds present.

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THE ECONOMIC FEASIBILITY OF MUNICIPAL WATER SOFTENING IN CALIFORNIA[1]

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The disadvantages of hard waters are too well recognized to need discussion here. The desirability of soft water likewise needs no comment. In the light of present day technic any water can be softened. The consideration is not one of technic, merely one of cost.

In this paper we consider the economy of water softening only from the standpoint of the domestic consumer. While in this connection there may be a number of distinct considerations involved, most of them are appeals to the esthetic; pleasantness, the effect on hair and skin, the effect on laundry, and similar conditions. These are real, but nevertheless, intangible, in that they cannot be evaluated in monetary terms. Hard water does affect soap consumption and there we have an item that we can deal with in economic terms.

Laundries have long since recognized this fact and have effected considerable savings by developing soft water supplies either natural or treated. For them it has been demonstrated to be economically feasible.

Actual soap saving in a municipality due to the use of softened water has only recently begun to receive attention. The studies that have been made vary in magnitude and manner of treatment and can by no means be considered universal in application. Practically all of these studies have been made upon midwestern or eastern water supplies. The writers have been unable to find any detailed studies of California supplies and inasmuch as there exist a number of features of water supply somewhat peculiar to that section it was thought that a survey of the economic possibilities of municipal softening in California might be of value. This was especially possible in view of the high per capita consumption in that state.

[1] Extract of thesis presented to Committee on Graduate Study in partial fulfillment of the requirements for the Degree of Engineering.

Since the following studies have been guided and based to a certain extent on similar studies made elsewhere, it is pertinent to first consider some of the more outstanding. Comment for the most part will be reserved. Linn (1), City Engineer of Grand Forks, North Dakota calculated a 2 percent return on the estimated investment involved in softening. Snyder (2) at Ohio State University determined soap losses experimentally. Unsoftened Scioto River water demonstrated a soap consumption of 119 pounds per capita per year as compared with 38.5 pounds with Columbus City softened water. Hoover (3) has reported favorably on municipal softening using

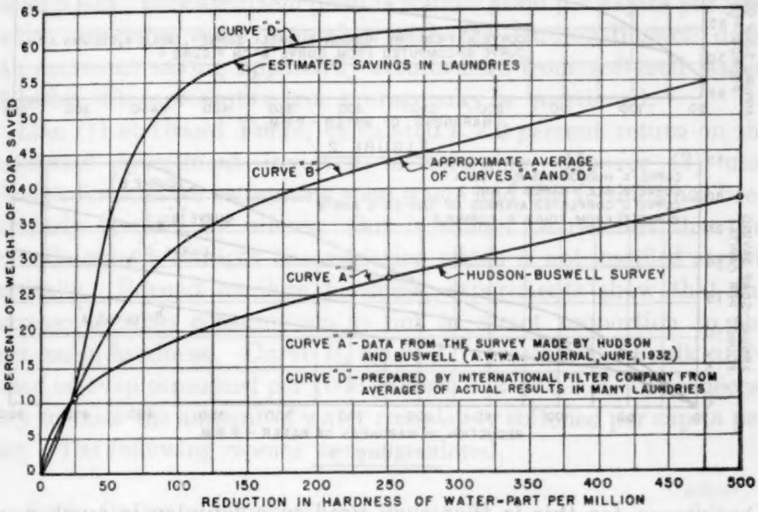

FIG. 1

Foulk's formula (4) as a basis for estimating soap saving of the high per capita consumption in that state.

Probably the most comprehensive of the recent economic studies are those by Hudson and Buswell (5) in four mid-western cities. Their survey consisted of a thorough canvas of each city to find every retail store handling soap. All kinds of soap and soap products were included. The hardness in the cities varied from 45 in one city to 555 p.p.m. in another. Some of the Hudson and Buswell results are used as the basis for the curves on figures reproduced later herein.

Comparing further the surveys made by Hudson and Buswell, a curve has been constructed, Curve D, figure 1, prepared by the International Filter Company (6) from averages of actual results in a

great many laundries. This shows the estimated, not guaranteed, savings in an average laundry if Zeolite softened water is used instead of hard water. It shows that appreciable savings can be realized even with three or four grain water. Comparing these results with the Hudson-Buswell survey it is found that the laundries show a much higher percent saving of soap when soft water is used.

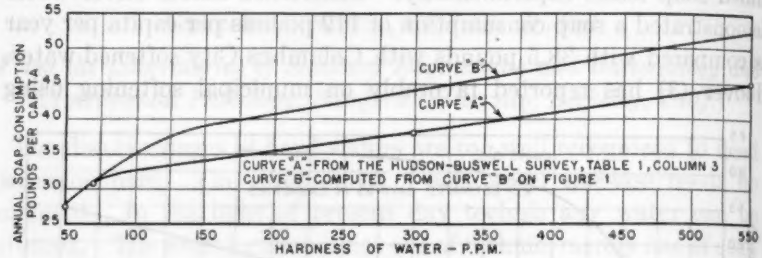

FIGURE 2

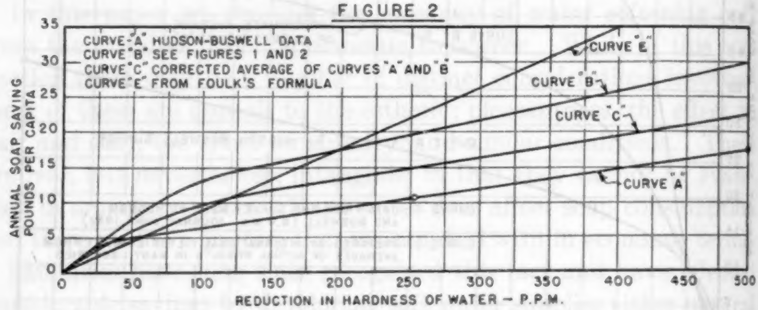

FIGURE 3

One reason for this is that soap used in a laundry is much more efficiently used than the soap in a household. However, this one factor cannot account for such a large difference. From an inspection of Curve A, figure 1, it will be seen that the curve takes a sharp rise that is closely comparable to the laundries' curve, then flattens out very suddenly. Lack of intermediate points makes it impossible to know whether or not the curve would flatten out or continue to rise. From the position of the control points, the rise in any case would be very slight. It may be that the flattening (Curve A, figure 1) is due to lack of sufficient correction for household softeners and cisterns. The two control points are from the Chicago-Heights and Champaign-Urbana using waters with a hardness of 555 and 298 p.p.m., respectively. Chemists estimate in a city of 40,000, using a water with 300 p.p.m. hardness, there is a soap waste of a ton per day. Reference to

the Hudson and Buswell data shows a city of 40,000 inhabitants with a soap waste of 1,140 pounds per day, a difference of 43 percent.

Snyder (2) at Ohio State University determined soap losses experimentally using two types of water. The first, filtered, unsoftened Scioto river water, had an average hardness of 270 p.p.m. The consumers were a single family of five. Calculations based on data from one week's consumption indicated 119 pounds of soap used per capita per year as compared with the highest figure of the Hudson-Buswell survey of 44.9 pounds per capita per year.

The second water, Columbus softened water with a hardness of 80 p.p.m., indicated 38.5 pounds consumption per capita per year which compares more favorably with the Hudson-Buswell data. An enormous saving apparently results here from softened water. Whether this represents a true average may be questioned.

Linn (1) at Grand Forks, calculated a 2.0 percent return on the estimated investment involved in softening. Hoover (3) uses Foulk's formula for estimating soap waste and this formula has been similarly invoked by others. But it should be recalled that this formula gives a straight line variation which is not justified experimentally. Beyond medium hardness, experiments show that the increase in soap consumption is not in direct proportion to the increase in hardness. Curve E, figure 3, represents the Foulk curve based on soap consumed per 1000 gallons = 2 + 0.2 H. It is necessary to know the amount of water completely softened per capita per day. The following reports were considered.

	gallons
Foulk—Geological Survey of Ohio Bulletin 29	0.9
Report Special Committee Madison, Wisconsin	1.7
City St. Louis Report of Water Commission	1.2
Average	1.2

From these assumptions the following results were obtained:

HARDNESS REMOVED BY SOFTENING *p. p. m.*	LOSS PER CAPITA PER YEAR *pounds*
65	5.7
115	10.0
165	14.5
215	18.8
265	23.2
315	27.6
365	32.0
415	36.4

Curve E, figure 3 represents these data.

Various experimental data show a variation of from 0.03 to 0.209 pound of soap wasted per 1000 gallons per 1.0 p.p.m. removed hardness. Variations in composition of soap and type of hardness will in part account for this.

The preceding material indicates the difficulty of constructing a curve representing a true average. Two such curves are here presented. The first was drawn as an average between the first "average" curve and the Hudson-Buswell curve, with the Foulk curve and the results from the Masonic Home investigation as guiding factors. The curve (Curve C, figure 3) has been adopted for the final calculations of soap waste and the results are shown in Column 9, table 1.

The data utilized in these studies and presented in table 1 were obtained by means of questionnaires to cities, the investigation covering about three-fifths of the population of the state, a fairly representative cross section. Detailed discussion of the chart and its significance follows.

RESULTS OF SURVEY

Columns 1 and 2

In some instances other cities are included in the water supply system beside the city mentioned. The population in every case is the estimated population served by the water system during the year 1932.

Columns 3 and 4

The annual water consumption was obtained from each city by means of a questionnaire. Some annual consumptions were for a calendar year and some were for a fiscal year. This makes no difference because the total annual consumption will be the same in both cases. Columns 4 and 5 were computed from columns 2 and 3. Column 5 is the daily per capita consumption in gallons.

Column 5

The estimated plant capacity is expressed as a daily rate. In every case sufficient allowance is made for the future before additional capacity is required. Only the small cities will have but one softening plant, say those below five million gallons per day. The figures in this column then represent the sum total of the estimated plant capacities for each city. This is done for convenience and is without any noticeable discrepancy. For example, the complexity of the

TABLE 1

Data on possible savings from water softenings in California cities

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CITY	POPULATION	ANNUAL WATER CONSUMPTION	PER CAPITA CONSUMPTION	PLANT CAPACITY	AVERAGE HARDNESS ($CaCO_3$)	HARDNESS TO BE REMOVED	EFFLUENT HARDNESS	ANNUAL SOAP SAVING	ANNUAL SOAP SAVING	PLANT COST	ANNUAL FIXED CHARGES	ANNUAL COST TREATMENT	TOTAL ANNUAL COST	TOTAL ANNUAL SAVING	RETURN ON INVESTMENT
		gallons	*gallons*	*million gallons*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*pounds*	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*	*dollars*	*per cent*
Los Angeles	1,290,000	55,500,000,000	118	225	150	85	65	11,000,000	1,315,000	4,500,000	405,000	566,000	971,000	344,000	7.7
San Francisco	660,000	18,410,000,000	77	80	137	72	65	5,100,000	614,000	1,600,000	144,000	160,000	304,000	310,000	19.4
East Bay District	500,000	12,500,000,000	68	42	60	0	60								
Long Beach	145,000	5,300,000,000	100	20	50	0	50								
Sacramento	100,000	8,123,000,000	222		61	0	61								
Pasadena	96,000	4,751,031,750	135	20	138	73	65	744,000	89,200	400,000	36,000	41,600	77,600	11,600	2.9
Glendale	63,000	3,075,362,000	136	12	170	105	65	620,000	74,200	264,000	23,800	38,800	62,600	11,600	4.4
San Jose	100,000	2,661,462,000	73	12	212	147	65	1,130,000	136,000	264,000	23,800	47,000	70,800	65,200	24.7
San Bernardino	38,000	1,942,000,000	140	8	154	89	65	342,000	41,000	176,000	15,800	20,500	36,300	4,700	2.7
Stockton	57,000	1,544,000,000	73	8	80	0	80		0	0	0	0	0	0	0
Santa Barbara	35,000	1,357,976,000	106	6	406	341	65	612,500	73,500	132,000	11,900	55,000	66,900	6,600	5.0
Alhambra	30,793	1,317,071,250	117	5	154	89	65	278,000	33,300	112,000	10,050	14,100	24,150	9,150	8.1
Bakersfield	30,000	2,878,000,000	262	10	96	0	96								
Pomona	24,000	911,000,000	104	5	82	0	82								
Redlands	18,400	3,091,000,000	460		134	69	65								
Burbank	16,500	821,616,000	136	4	191	126	65	173,200	20,800	92,000	8,300	12,400	20,700	100	
Ontario	13,300	686,000,000	141	3.5	140	75	65	105,000	12,600	87,500	7,900	6,160	14,060	−1,460	
Palo Alto	15,200	776,168,000	140	3.5	187	122	65	159,600	19,150	87,500	7,900	11,400	19,300	−150	
Modesto	15,000	1,687,492,000	308	6	123	58	65	99,000	11,900	132,000	11,900	11,600	23,500	−11,600	
San Mateo	15,000	511,000,000	93	3	304	239	65	213,000	25,600	75,000	6,750	14,650	21,400	4,200	5.6
Monrovia	12,800	1,098,733,573	235	4	350	285	65	200,000	24,000	92,000	8,300	36,400	44,700	−20,700	
Anaheim	12,000	451,315,100	103	2.5	196	131	65	129,000	15,000	62,500	5,600	7,100	12,700	2,800	4.3
Hermosa-Redondo	11,000	672,000,000	162	3	180	115	65	112,000	13,500	75,000	6,750	9,275	16,025	−2,525	
Fullerton	9,000	422,122,000	129	2	192	127	65	95,500	11,450	50,000	4,500	6,450	10,950	500	1.0
South San Francisco	7,700	497,000,000	178	2	250	195	65	97,750	11,700	50,000	4,500	11,400	15,900	−4,200	

Los Angeles water supply system would require about ten plants ranging from 15 to 40 m.g.d. and San Francisco would have to have at least six plants considering the present layout and these plants would range in size from 5 to 35 m.g.d. The smaller the city the simpler the problem becomes and the use of one large plant for the entire city is often possible.

Columns 6 and 7

The figures in these columns are supposed to represent an average value for the total hardness of each system.

The attempt was made to weigh the hardness of each supply, but in a number of instances insufficient data were received. Some cities gave the actual average hardness of their supplies. Where insufficient data were received, a conservative figure was estimated as in the case of Los Angeles and San Francisco, the latter being more accurate than the former since only 15 percent of the total supply was omitted in arriving at an average hardness.

The following cities reported their average hardness directly: East Bay Municipal Utility District, Long Beach, Sacramento, San Jose, San Bernardino, Stockton, Santa Barbara, Bakersfield, Pomona, Ontario, San Mateo, Monrovia, Hermos-Redondo, and South San Francisco.

The rest of the cities reported an analysis and amount of water used from each source throughout the system—thereby permitting the computation of a weighted average hardness.

Column 8

All cities having a hardness of 100 p.p.m. or above were considered desirable, for removal of hardness to give an effluent with 65 p.p.m. This value is considered by authorities to be the limit to which water should be softened from both the financial and quality viewpoint. This value can be reached without any difficulty by any of the processes now available.

Columns 9 and 10

The annual soap saving in pounds is computed by means of Curve C on figure 3. For example, the City of Los Angeles is to have 85 p.p.m. of hardness removed (Column 7). From curve "C" the annual per capita saving in soap will be 8.5 pounds. Then the total annual saving is $8.5 \times 1,290,000 = 11,000,000$ pounds. The results

in column 10 were obtained using a figure of 12 cents per pound for soap. This is a conservative price for soap based on the average cost of all household soaps. Present prices show that household soaps vary from 5 to 30 cents per pound and about 70 to 80 percent of the soap used varies from 5 to 13 cents per pounds and the remainder averages 30 cents per pounds. Assuming that the above distribution of household soap is approximately correct a value of 12 cents per pound is about right, and any higher value would not be justified.

Column 11

Plant costs are more or less arbitrary. There is a wide variance in the unit cost of the existing plants. This is due in part to change in prices and differences in methods of treatment.

A range of costs per million gallons capacity recommended by the International Filter Company has been used. This information was obtained at the Pacific Coast Offices in Los Angeles through the courtesy of R. B. Thieme. The figures are only approximate, but they are based on chemical treatment and not zeolite plants. The costs are estimated by International Filter Company, to vary from $18,000 to $25,000 per million gallons depending upon the size of the plant.

In estimating the costs in column 11 the following figures for the different cities were used per million gallons:

Los Angeles, San Francisco and Pasadena, $20,000; Glendale, San Jose, San Bernardino, Santa Barbara, Alhambra and Modesto, $22,000; Burbank and Monrovia, $23,000; Ontario, Palo Alto, San Mateo, Anaheim, Hermosa-Redondo, Fullerton and South San Francisco, $25,000.

Column 12

The annual fixed charges on a plant are considered as a part of the total annual cost of treatment. This sum takes care of interest on the investment, depreciation and maintenance. Nine percent of the total investment has been used to include the annual fixed charges, 6 for interest, $2\frac{1}{2}$ for depreciation and $\frac{1}{2}$ percent for maintenance.

Column 13

The annual cost of treatment is probably the most difficult to obtain. The best way to arrive at this figure is to take an average of the actual treatment costs of plants now in operation. Complete

data from many of these are not available. The figure adopted was 12 cents per p.p.m. of hardness removed per million gallons. For example, the City of San Francisco used 18,410 m.g. of water in the year 1932. The proposed removal of hardness is 72 p.p.m. The annual cost of treatment is $0.12 \times 72 \times 18{,}410 = \$160{,}000$.

The adopted figure is based on two lime-soda plants and three zeolite plants actually in operation. No attempt has been made to consider a particular process in this study. The treatment cost averages both the zeolite and the chemical processes, but the plant costs are based upon chemical treatment only.

Zeolite treatment will be considered in a few cases for the purpose of finding a possible lower cost of softening.

Column 14

Total annual cost of treatment is the sum of the treatment cost and the fixed charges.

Columns 15 and 16

The total annual saving is the difference between the computed soap saving (column 10) and the total annual cost (column 14). The percent return on the investment is found by expressing the ratio of annual savings to plant investment as a percentage.

A return of 10 percent or more on the investment was considered as profitable. This is an arbitrary figure, but previous studies in economics tends towards the use of 10 percent or more as profitable return. The low figure has been used in order to give the benefit of the uncertainty to municipal water softening.

SUMMARY

Seven cities are listed on table 1 that have not been investigated for the possibilities of softening their supplies. Six of these cities have soft water, if we consider a water hard that is over 100 p.p.m. hardness. The six cities mentioned have such a high water consumption (460 gallons per capita per day) that they were not included.

The East Bay and the Sacramento water supply systems are both surface supplies that are filtered and chlorinated. They are probably the two best domestic and industrial supplies in the state. The citizens do not have to worry about hard water for it is softer than most artificially-softened water.

Long Beach has the softest supply listed on table 1 (50 p.p.m.). Obviously softening is not indicated there.

Bakersfield, Stockton and Pomona have soft water supplies, 96, 82, and 80 p.p.m. hardness, respectively. With such low figures it would be difficult to convince these cities that their supplies should be softened. From the soap saving chart it will be seen that the soap saved, in the case of Bakersfield, if the hardness of the water were reduced to 65 p.p.m., would amount to $12,600 and the fixed charges on a 10 million gallon plant would be $19,800. It would be absurd, therefore, to consider the cities of Stockton and Pomona whose water supplies are softer than that of Bakersfield.

The City of Redlands was not considered because of the high water consumption. The average daily consumption for the year 1932, was 460 gallons per capita. Only 190 gallons per capita were used for domestic purposes, but since there is only one distributing system the water for irrigation has to be considered. It is obvious that it would be uneconomical to soften water supply of only 134 p.p.m. hardness when more than half the daily consumption is used for agricultural purposes. This consideration will be discussed in more detail later on.

Since a 10 percent return on a municipal investment is considered as profitable it will be observed that from table 1 only two cities show a return of 10 percent or more on the estimated investment; namely, San Francisco and San Jose. The remaining cities show less than 8 percent return on their respective estimated investments in municipal water softening. Of the remaining 16 cities, 12 have more undesirable water supplies (in respect to hardness) than San Francisco and 4 have more undesirable than San Jose. Without further investigation this would seem unreasonable. There is a reason for this difference and it lies in the fact that San Francisco and San Jose have the lowest per capita water consumption of all of the other cities considered. As the per capita water consumption increases, the plant cost and treatment cost increase directly, while the per capita soap saving remain constant. Therefore, the controlling factor is the per capita water consumption, provided, of course, the hardness of the supply is to be reduced about 50 p.p.m. or more. If less than 50 p.p.m. were to be removed the water would be considered soft and softening would not be justified in that case.

Since the per capita water consumption is a controlling factor in this problem let us eliminate from further investigation those cities of relatively high per capita water consumption, namely, Pasadena, Glendale, San Bernardino, Burbank, Ontario, Palo Alto, Modesto,

Monrovia, Hermosa-Redondo and South San Francisco. About five of these cities use a considerable portion of the water charged to per capita consumption for agricultural purposes. If water for agricultural purposes were distributed on a separate line, the remainder of the water for domestic and industrial use could probably be softened with a profitable return on the investment. However, the cost of a separate system for irrigation introduces a complication that would require an individual study for each city. Even if it were found profitable to install both a water softening plant and an additional distribution system, it would still be difficult to convince the public of the benefits derived, since none of the waters in these cities is very objectionable in regard to hardness except Monrovia (350 p.p.m.). The other cities in mind, San Bernardino, Burbank, Ontario and Modesto have medium hard waters. Their respective hardnesses are: 54, 191, 140, and 123 p.p.m.

Since we have eliminated those cities of relatively high per capita water consumption, the remaining cities to be investigated further to see if there are any remote possibilities are: Los Angeles, Santa Barbara, Alhambra, San Mateo, Anaheim, Palo Alto and Fullerton.

Santa Barbara

This city has the hardest water supply of the twenty-five water supplies considered, and water softening only shows a 5 percent return on the investment. This seems strange when San Jose has a water supply half as hard as that of Santa Barbara and still shows a 24.7 percent return on the estimated investment. The reason that this difference occurs lies in the fact that soap saving does not increase directly with an increase in the hardness of water (see Curve C, figure 3), while the cost of softening does increase directly with the hardness removed. It would be better then to cut down the cost of treatment by removing less hardness, which would not effect a direct decrease in soap saving. For example, let us assume removal of 150 p.p.m. hardness from the Santa Barbara supply. The annual soap saving would be $11.5 \times \$0.12 = \$46,400$. The cost of treatment for this removal would be $0.12 \times 150 \times 1358$ mg. $= \$24,400$. Since the fixed charges remain the same the total annual cost of treatment is \$36,300 which represents an annual saving of \$12,100 or a 9.2 percent return on the estimated investment. Similarly any reduction in hardness greater or less than 150 p.p.m. realizes a return of less than

9.2 percent. In other words the most economical removal according to the above method is to reduce the hardness from 406 p.p.m. to 256 p.p.m.—this still classes the water as a hard water and the benefits of soft water (except soap saving) are not realized. This would hardly justify this small amount of hardness removed.

It might be well to consider another type of treatment. It must be remembered first, that the above figures for plant cost are based on chemical treatment and the operating cost is an average of both the chemical and zeolite processes. In the zeolite process, the water treated is of zero hardness. This means that for a municipal water supply only partial treatment is necessary to give a residual hardness of 65 p.p.m., that is, part of the water is treated to give zero hardness and is mixed with part of the raw water in such proportions as to give the desired effluent hardness. The plant capacity for a zeolite treatment is not quite as large as that for a chemically-treated water for the same supply. However, a zeolite plant costs approximately $5,000 more per million gallons than does a chemical treatment plant. Therefore, the extra cost of the zeolite plant in most cases balances the reduction in required capacity, bringing the original plant investment for the two types of treatment to nearly the same value. In other words, from the data available on the plant costs for the two processes it would hardly be reasonable to say that the plant cost for the zeolite process would be less than that for a chemical process. In considering the cost of treatment all figures available in literature give the cost of treatment based on water delivered and not the amount treated. These figures vary from 11 to 14 cents per p.p.m. of hardness removed per million gallons of water delivered. Generally speaking, then, a typical zeolite plant would not give a treatment cost less than 12 cents per p.p.m. removed per million gallons. Summing up these generalities, the figures used throughout in this study for both plant costs and treatment costs are probably the lowest figures that could be realized regardless of the type of process used.

Since it has been shown that it is not reasonable to use any other figures in arriving at a lower total annual treatment cost the cities of Los Angeles, Alhambra, Anaheim, Palo Alto and Fullerton deserve no further consideration in their respective possibilities for municipal water softening, since they are within the limit of economical reduction in hardness.

San Mateo

With the elimination of the above cities, the only one left for further consideration is San Mateo. The return on the investment when a maximum removal of 239 p.p.m. hardness is considered appears to be 5.6 percent (see figure 1). Let us see what the results would be if only 150 p.p.m. of hardness were removed. From Curve C, figure 3, the annual soap saving would be $11.5 \times \$0.12 \times 15{,}000 = \$20{,}700$, and the annual treatment cost for this removal would be $\$0.12 \times 150 \times 511$ mg. $= \$9200$. Since the fixed charges remain the same the total annual cost of treatment would be $\$6750 + \$9200 = \$15{,}950$, and the total annual saving would be $\$20{,}700 - 15{,}950 = \$4750$. This saving represented as percent return on the investment is 6.35 percent. Similarly any reduction in hardness less than or greater than 150 p.p.m. will give a return of less than 6.35 percent on the estimated investment.

Therefore, from all the considerations given it does not appear that municipal water softening is profitable for the City of San Mateo.

Since all the cities listed have been considered from every possible viewpoint the conclusions for this report follow.

CONCLUSIONS

1. San Francisco and San Jose are the only cities of the twenty-five considered that show an economic feasibility for municipal water softening, in terms of soap saving, and one of these is to be supplied with water within a few weeks that will give it the softest water supply in the state without any treatment. Therefore, San Jose appears to be the only city worth while considering for water softening from an economic viewpoint. It might be feasible then, other things being equal, for San Jose to install a municipal water softening plant.

2. Santa Barbara, whose water is the hardest in the state, shows only 5.0 percent return on the estimated investment when the water is reduced to 65 p.p.m. and a 9.2 percent return when it is reduced to 256 p.p.m. The former is not advisable because the returns do not justify the investment, and the latter is not advisable because the water is still hard.

3. In the remaining cities it would be uneconomical to soften even hard supplies because of the high per capita consumption. In some of these cities there is an extra burden added and that is water for agricultural purposes which increases the per capita consumption to above 150 gallons per day. Regardless of irrigation, the average per

capita consumption in the State of California is high—the only two cities to show profitable results had a low consumption rate.

To show further the effect of low per capita water consumption, the City Engineer (1) of Grand Forks, North Dakota, investigated the savings to the consumer through municipal water softening and by his figures he arrives at a 2 percent return on the estimated investment. From the figures used throughout in this study a return of 12 percent is realized. The difference in the two lies mainly in the fact that depreciation and maintenance were not considered in the former and the cost of treatment was low because the softening process was added to the purification process already in operation. That both calculations show a profitable return on the investment is

TABLE 2

Return on investment

CITIES	AT 16 CENTS PER POUND	AT 12 CENTS PER POUND
	percent	*percent*
San Jose	41.7	24.7
San Francisco	32	19.4
Alhambra	18.2	8.1
Los Angeles	17.5	7.7
San Mateo	16.9	5.6
Santa Barbara	23.6	5.0
Glendale	13.9	4.4
Anaheim	12.6	4.3
Pasadena	10.3	2.9
San Bernardino	10.4	2.7
Fullerton	8.8	1.0

the result of only 70 gallons per capita consumption per day. As the per capita water consumption increases the plant cost increases directly and the treatment cost increases directly while the saving remains constant.. Therefore only cities with a daily per capita rate of between 70 and 90 gallons per day, will show profitable results in regard to municipal water softening.

4. The reason that cities with very hard water, namely San Mateo, Santa Barbara, did not give the desired results is that soap saving accruing from softened water does not increase directly with the removal of hardness, while the cost of treating does increase directly.

5. It is entirely possible to arrive at figures favorable to water softening if a higher cost of soap is used. For example, if soap is assumed to be 16 cents per pound as an average cost including all household soaps instead of 12 cents per pound, the City of Santa Barbara would save the citizens $31,000 in soap instead of $6000 (annually) when the water is softened from 406 p.p.m. to 65 p.p.m. This higher price for soap gives a net return of 23.6 on the investment instead of 5 percent as before. Similarly, the cities in table 2 show these results with soap at 16 cents per pound in terms of percent returns on the investment.

The results shown in table 2 illustrate the danger in using too high an average cost for soap. Since it has been pointed out that 12 cents per pound is a reasonable figure, any results occurring from a higher soap cost will be misleading.

6. Every situation possible has been considered to favor the possibility of municipal water softening in California and from the results obtained, it appears that there is but one city that would profit by municipal water softening, San Jose. As for the entire state as a general case there are no possibilities at present for municipal water softening. However, as time goes on the water may become harder, and with this in mind, California may yet have to consider water softening as a municipal enterprise.

7. The only other possibility lies within the Metropolitan Water District. In the future all of the cities included in this district will be using Colorado River water which necessitates purification and softening before it can be used. The following cities are in the district: Los Angeles, Beverly Hills, Pasadena, Compton, Long Beach, Fullerton, Anaheim, Santa Monica, Burbank, Glendale, San Marino, Torrance, and Santa Ana.

8. Since soap saving has been the only determinable factor in this economic study, it does not mean that it is the only consideration. There are many others equally important as previously mentioned that must not be ignored. However, it is impossible to determine the maximum that any individual would be willing to pay for soft water. The latter becomes a problem that lies in the realm of subjective utility rather than of objective economic value.

The authors wish to express their appreciation of the courtesy of those Cities and their Officials who have so generously furnished us with the data discussed in these studies.

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MODERN DEVICES FOR IMPROVING WATERWORKS SERVICE

By L. A. Smith

(*Superintendent, Water Department, Madison, Wis.*)

When I first took the office of Waterworks Superintendent at Madison, nearly twenty years ago, it was common practice to shut off water for the repair of mains, services, hydrants or valves at any time that it was convenient to the Water Department by simply notifying the property owners. In some cases water was shut off for four or more hours. This was poor service and the time has passed when water can be shut off except in actual cases of necessity such as a main break of considerable consequence. Our consumers are paying for the best possible service, and good service should mean continuous service. In order to give our customers as nearly as possible continuous service we have adopted three changes in policy and have made use of several modern devices—all of which have reduced the number of times that water has to be shut off and the length of time that it is shut off.

EMERGENCY SERVICE

We maintain a regular night man for emergency service which can be handled by a single person. We also operate a night crew from 10:00 P.M., to 6:00 A.M., to take care of valve, main and hydrant repairs in which it is necessary to shut off the water. Both the emergency night man and the night crew are provided with trucks for prompt service.

GATE VALVES IN MANHOLES

The second change is the adoption of the policy of building manholes around all of our gate valves prior to street improvements so that no excavation is required in case of a valve repair. We have also adopted the policy of installing a gate valve on every hydrant lead so that it is not necessary to shut off the main in case of a hydrant repair.

AQUAPHONE

One of the simplest and most effective devices in locating leaks is the aquaphone. This is simply an old fashioned telephone receiver with a pointed pin inserted at the place where the wire ordinarily enters the receiver. This device amplifies the volume of sound so that leaks can be located which cannot be heard under ordinary circumstances. The simplicity and low cost of the aquaphone justifies its use by even the smallest water utility. The aquaphone is used in three ways: First, by meter inspectors when they are reading the meters to find out whether there are any service or main leaks in the vicinity. When the characteristic hissing sound is heard the meter reader reports the location and a work order is issued. Second; the aquaphone is also used by our hydrant inspector to detect leaks in hydrants or mains and services in the vicinity of hydrants. When it is determined that a leak exists in a certain locality quite often effective results can be obtained by driving a pointed rod down to the main and listening, which is the third method we recommend for the use of the aquaphone. The City of New York uses aquaphones to the almost exclusion of other sound amplifying devices with very successful results.

ELECTRIC LEAK LOCATOR

There is another device—the electric leak locator—which consists of a flat plate with four pointed lugs which can be inserted into the ground electrically connected to an amplifier with storage batteries and ear phones. This device provides a much larger amplification of sound and is of value in detecting extremely small leaks which could not be heard with an aquaphone. However, its use is limited to locations where the traffic is light, and if it is desirable to use it in the business district it can only be used successfully at night. This device is extremely valuable in locating leaks under pavements where a rod cannot be driven down to the main because of its sensitivity. By its careful use a leak can be so accurately located that it is necessary to make only one pavement cut.

The electric pipe locator has saved our department large sums of money in the past by enabling us to accurately locate service and distribution lines. This device consists of a buzzer, coil, dry cells and ear phones, together with 100 feet or so of copper wire. If a service enters a house and we have no record of its location an electrical connection is established by connecting one side of the battery

to a sill cock of the house where the service location is unknown and connecting the other side of the battery to another sill cock, or hydrant in the immediate vicinity. When the buzzer is turned on an electrical contact is thus established and by using the coil and ear phones and examining the area within the electrical circuit a person can tell definitely when they have passed over the pipe line in question. We have located services which were installed a good many years ago in rather peculiar locations and of which we had no record. In general this would be impossible to do by any other means except by actual excavation.

DIP NEEDLE

Another device which has been commonly used for a good many years and which we consider so valuable that we have equipped every service truck with one, is the dip needle. This is also a comparatively inexpensive and simple device and is recommended for common use. The dip needle enables a person to locate valve boxes or service boxes which are buried. In a great many cases these are only covered with a few inches of dirt and their location can be readily determined. We have located service boxes which have been covered with 18 inches of dirt by use of this device. It is extremely valuable in locating service and valve boxes when snow and ice are on the ground.

We have also used the ordinary physician's stethosocope to great advantage, particularly within buildings in definitely locating leaks under basement floors, or in walls. The stethoscope provides an amplification slightly greater than the aquaphone and has the advantage that it has two ear phones so that extraneous noises are largely eliminated.

BLACK BOOK

Another item of value, although it cannot be properly called a device, is our so-called "Black Book." We maintain in the City Engineer's office large record books with cloth backed sheets approximately 24 x 30 inches on which are shown to scale the location of all mains, hydrants, valves and services, giving accurate dimensions from the property lines. Photostatic copies of these original records are made and bound in book form. One of these books is provided for each of our service trucks, one is available in the Water Department office, one at the Pumping Station and one at the Service Building. This enables our employees to make prompt shut offs

and saves a considerable amount of time which would otherwise be spent in consulting the original record. This has the further advantage in providing a duplicate of our original record should it be destroyed in any way.

The Water Department operates four unit wells and two booster pumping stations which are electrically driven, as well as a steam driven D. C. generator at the Main Station. Wherever electricity is used there is the danger of radio interference and we have a portable R. C. A. radio with which all of our electrical units are tested periodically and particularly when there is a complaint of radio interference.

There is no question in my mind but that the use of modern devices for locating pipe lines, service boxes and leaks are fine investments and, undoubtedly, pay for themselves from an economic standpoint. We have approximately $500.00 invested in these devices and I am satisfied that they return annually several times this amount in the saving of labor. There are two definite advantages, however, other than economic—first, that we are able to give better service and, second, that excavations are not made without definitely knowing the exact point at which to dig. We also eliminate a large part of the criticism which occurs when pavement cuts are made, particularly in new pavements.

(Presented before the Wisconsin Section meeting, September 26, 1934.)

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Modern Filter Plant in China Built by Coolie Labor. Ellwood H. Aldrich. Eng. News-Rec., 110: 490–1, 1933. Brief description of 1-m.g.d. rapid sand filter plant recently completed by Lingnan University, which consists of settling basins, screens, spray nozzle aërators, mechanical mixing chamber (15-minute detention), coagulation basin (4-hour detention), 3 filters, and chlorination equipment. Operation is largely automatic. Brief analysis of costs is included. The total cost, exclusive of engineering, was $65,000.—*R. E. Thompson (Courtesy Chem. Abst.).*

Non-Slip Hydraulic-Fill Dam for San Diego. H. N Savage. Eng. News-Rec., 111: 33–6, July 13, 1933. Climate in San Diego is arid, with fairly well defined 11-year intervals between seasons of heavy rainfall and runoff, so that supply has to be stored for intervening years. Existing reservoirs, Hodges, Morena, Barrett, and Otay, provide net safe yield of 14 m.g.d. Recourse to underground sources is required each summer and during emergency periods. Ultimate source will be Colorado River, negotiations having been completed for 100-m.g.d. supply from that source, when required, to be conveyed through All-American Canal and by 1000-foot pumping lift and 28-mile tunnel to San Diego River watershed above El Capitan reservoir now under construction. Latter will have capacity of 118,000 acre-feet, including 10,000 allotted for irrigation, and will provide regulated 10-m.g.d. supply. El Capitan dam, design and construction of which is described, will be hydraulic-fill and rock-embankment structure, 217 feet high above streambed and 1200 feet long on crest. Program calls for completion in October, 1934 Population is about 160,000.—*R. E. Thompson.*

Sewers and Water Mains Laid by Relief Labor. L. M. Bush. Eng. News-Rec., 110: 832–3, June 29, 1933. Brief data are given regarding costs of 16.5 miles of mains laid by relief labor in Oklahoma City.—*R. E. Thompson.*

Architecture Applied to Elevated Steel Tanks. Eng. News-Rec., 110: 403–5, March 30, 1933. Illustrated description of new elevated steel tanks in Baltimore, Md., and Tallahassee, Fla., which, by virtue of radical departures in structural make-up, achieve distinctive architecture in steel itself. Baltimore tank has capacity of 300,000 gallons, is 42 feet in diameter and 102 feet high from ground to overflow, and has 30-foot range in head. Tallahassee tank has

capacity of 400,000 gallons, diameter of 56 feet, 24-foot range of head, and height of 102 feet to overflow line.—*R. E. Thompson.*

Improved Prospects in Recent Weeks in Waterworks and Sewerage Construction. A. E. Berry. Engineering and Contract Record, 47: 524–5, May 31, 1933. Brief outline of works projected in Ontario.—*R. E. Thompson.*

Operation of Swimming Pools. R. F. Heath. Can. Pub. Health J., 14: 123–7, 1933. A general discussion of the sanitation of swimming pools, including recirculation and purification of pool water, methods of cleaning pool, and supervision of bathers. Importance of operating records is stressed.—*R. E. Thompson (Courtesy Chem. Abst.).*

Welding Methods Used for Assembling 35,000 Feet of Oil Pipe Line for Montreal East Refinery. H. M. Lyster. Contract Record and Eng. Rev., 47: 259–61, March 15, 1933. Brief illustrated description of installation of two 12-inch and three 10-inch welded steel pipe lines, each about 7000 feet long. In all, 858 joints were made, and only one minor leak was found on testing.—*R. E. Thompson.*

Fire Hydrants Assembled in Water Department Shop. Seth M. Van Loan. Eng. News-Rec., 110: 413–4, March 30, 1933. Brief description of equipment employed and procedure followed in Philadelphia in assembling fire hydrants from bulk-stock materials and contract-purchased castings. Cost data are not available, but it is believed that shop assembly is step toward economy.—*R. E. Thompson.*

Milwaukee Builds a Welded Tank of 6,000,000-Gallon Capacity. Eng. News-Rec., 110: 589, May 11, 1933. Brief description of new covered 6-million gallon tank, said to be largest welded steel tank yet built. Tank is of flat-bottomed type, 165 feet in diameter and 37.5 feet high to overflow. Total weight is 700 tons. Specifications call for sandblasting ot entire tank and priming coat of lead chromate. Exterior will then receive two coats of aluminum paint and interior two additional coats of chromate of lead. Cost is estimated at $85,000. —*R. E. Thompson.*

Sacramento Sets New Standards in Pre-Treatment. Harry N. Jenks. Eng. News-Rec., 111: 1–5, 1933. Detailed description of new 64-m.g.d. pretreatment works which consist of a grit remover or detritor, aëration system made up of Sacramento-type spray nozzles and a riffled inclined slab, with forced ventilation for preventing reabsorption of odors, 4 mechanical mixing tanks, 56 feet in diameter and 21 feet deep (to water level), mixing being effected by a "spirovortex" pump designed by J., 2 Dorr traction clarifiers for prompt removal of preliminary sediment which is heavily charged with organic matter, and 4 shallow cross-flow settling tanks equipped with inclined plates for intercepting floc and Link-belt sludge collectors. Latter basins, termed "surfasettlers," were developed as result of studies conducted in experimental plant. All basins are provided with large inlets and outlets to avoid floc

dispersion. Fine sediment from final settling basins is returned to raw water to expedite floc formation. Earthquake-resistant construction was employed throughout, the shallow basins resting on pile clusters entirely above ground. Flexibility is a feature, 6 different sequences of mixing tank operation being provided for. Power requirement for mixing is about 0.6 h.p. per m.g. capacity. Provision was included for activated carbon, ammonia-chlorine, and pre- and superchlorination, should experience indicate these treatments to be desirable. Cost per m.g.d. was $7,000, inclusive of piles, or $6,000 exclusive of piles.—*R. E. Thompson (Courtesy Chem. Abst.).*

Redesign and Construction of Prettyboy Dam. Eng. News-Rec., 111: 63-7, July 20, 1933. Details are given of revised plans rendered necessary by unforseen conditions disclosed during initial excavation. Dam is located on Gunpowder Falls, near mouth of Prettyboy Creek, about 15 miles above headwaters of present water supply development at Loch Raven. Water stored at Prettyboy will be released into the Gunpowder as needed at Loch Raven. Original plans called for concrete gravity-type dam 692 feet long and 147 feet high. Details of revised design given. Ultimate cost was $2,385,000.—*R. E. Thompson.*

De-moistured Air Aids Madden Dam Cement. Adolph J. Ackerman. Eng. News-Rec., 111: 11, 3, 1933. Facilities for unloading and storing cement for Madden Dam, Panama Canal Zone, under very damp climatic conditions, are described. Cement is received in paper bags and pumped by air pressure into steel silos, provision being made for desiccation of air supplied to pump. Handling loss at bulking plant is about 0.2 percent and transportation loss (from siding dam site) averages 0.16 percent.—*R. E. Thompson (Courtesy Chem. Abst.).*

Improvements to the Water Supply at Cap-de-la-Madeleine, Que. Romeo Morrissette. Engineering and Contract Record, 47: 681-3, July 12, 1933. Supply which is drawn from small pond fed by springs, contains fine sand. Small reservoir of 32,000 gallons capacity was effective as settling basin until new and larger pumps increased rate of flow. Recent improvements to correct this condition include open channels from springs to pond, equipped with concrete and wooden dams for controlling rate of flow into, and level of water in, pond, and concrete pumping reservoir, 217 feet long, 62 feet wide, and 10 feet deep, made up of 3 basins and equipped with stilling baffles. Additions to distribution system have also been completed recently.—*R. E. Thompson.*

Lining the Coast Range Tunnel for Hetch Hetchy Water. Eng. News-Rec., 111: 107-10, July 27, 1933. Lining procedure on 28.6-mile, 10.5-foot tunnel for San Francisco water supply project is described in detail. Features of work include design for heavy squeezing ground and development of 3-shift placing system, operating from 3 points only, with maximum underground haul of 7 miles. Including 120,000 cubic yards of sub-lining which replaced timbering in squeezing ground, concrete volume will total about 500,000 cubic

yards. Lining thickness varies from minimum of 6 inches, in front of 8 x 8-inch timber sets, to 36 inches at heaviest section. Concreting has been timed for completion coincidently with driving operations this fall and opening of aqueduct is scheduled for spring of 1934.—*R. E. Thompson.*

Water Sampler Avoids Contamination by Air Bubbles. F. E. DANIELS. Eng. News-Rec., 110: 704, 1933. Brief illustrated description of river-water sampling apparatus devised by D., by means of which four 135-cc. samples may be collected directly in bottles in which tests, e.g., dissolved oxygen and biochemical oxygen demand, are to be conducted.—*R. E. Thompson (Courtesy Chem. Abst.).*

Castlewood Dam Failure Floods Denver. Eng. News-Rec., 111: 174–6, August 10, 1933. Castlewood dam, which failed on August 3, 1933, is described and damage caused by flood which followed failure is outlined. Dam, which was located on Cherry Creek, 35 miles southeast of Denver, forming 3500-acre-foot irrigation reservoir, consisted of rockfill placed downstream from masonry wall, 600 feet long on crest and 70 feet high above streambed. Failure was due to unprecedented runoff, estimated at 5,000–6,000 second-feet, topping dam to 1-foot depth over entire length. Erosion of lower toe of spillway, or displacement of rubble masonry in spillway section caused collapse of loose-rock fill composing main body of dam. Entire east half of structure, including spillway, went out, leaving west half standing. Construction of dam was completed in 1890.—*R. E. Thompson.*

Data on Castlewood Dam Failure and Flood. JOHN E. FIELD. Eng. News-Rec., 111: 279–80, September 7, 1933. Data are given regarding Castlewood dam, flood which resulted in its failure, cause of break, and damage caused by flood. Cause of break cannot be exactly known. Either the top or toe crumbled. Considering nature of riverbed at toe, it is reasonable to suppose that toe failed, that force of water rapidly carried away loose rock, and that pressure broke the rubble masonry.—*R. E. Thompson.*

Flooded Waterworks Requires Emergency Sanitation Measures. Eng. News-Rec., 111: 225–6, August 24, 1933. Rainfall of 3.3 inches within few hours on May 11 caused sudden flood stage of Vermilion River, from which supply of Streator, Illinois, is drawn. Boiler house and pumping station of Streator were flooded, polluted flood water poured into clear-water basin, and chlorination equipment was disabled. Planks and sand bags were used to prevent overtopping of flood protection wall around station, but pressure resulted in collapse of wall. Emergency supplies were brought in in tank cars and chlorinated by staff of State Department of Health and a few scattered wells were chlorinated and placarded. No water passed through system for 3 days. When pumping was resumed, emergency chlorination equipment was employed and system was thoroughly flushed with heavily chlorinated water. Not a single case of illness that could be attributed to water supply was reported.—*R. E. Thompson.*

Analysis of Flood Produced by Severe California Cloudburst. Eng. News-Rec., 111: 128, August 3, 1933. With maximum recorded precipitation of 4.34 inches in 5 hours, cloudburst in Tehachapi Valley, Southern California, resulted in flood peak averaging about 300 second-feet per mile, with several individual calculations exceeding 500 second-feet. Considerable damage resulted and 15 lives were lost. Probable frequency of such a storm is estimated at about 90 years.—*R. E. Thompson.*

New Water Plant Stresses Pre-Treatment. G. Gale Dixon. Eng. News-Rec., 110: 395–9, 1933. Detailed description of 40-m.g.d. purification plant completed in 1932 by Mahoning Valley Sanitary District to supply Youngstown and Niles, O. System consists of dam and impounding reservoir on Meander Creek, purification and pumping works immediately below dam, supply lines to cities, distribution reservoir at Youngstown, and standpipe at Niles. Purification plant consists of vacuum conveyers for unloading chemicals, draft-tube mechanical agitators, settling basins equipped for continuous sludge removal, carbonation chambers, and rapid sand filters. Although raw water hardness is only 140 p.p.m., it is softened by lime-soda method, with recarbonation and return of sludge, before final settling.—*R. E. Thompson (Courtesy Chem. Abst.).*

Corewall of 31 Caissons Sunk Under Air. Eng. News-Rec., 111: 215–9, August 24, 1933. Illustrated description of construction of concrete corewall about 1500 feet long formed by sinking pneumatic caissons to depth of 40 to 140 feet below original ground surface, an outstanding construction feature of new supply project of Metropolitan District of Boston. Corewall is part of earth dike being built to close depression in hills surrounding Quabbin Reservoir, which is to be formed by Quabbin Dam and dike, both being earth structures, former 170 feet high and 2340 feet long and latter 135 feet high and 2140 feet long. Brief outline of water supply project in general is included.—*R. E. Thompson.*

Hydraulic-Model Tests for Boulder Dam Spillways. E. W. Lane. Eng. News-Rec., 111: 155–9, August 10, 1933. Detailed account of spillway investigations which resulted in design of two side-channel type spillways of 200,000 second-feet capacity, discharging into outside diversion tunnels.—*R. E. Thompson.*

Worst Water in the West Made Fit to Drink. D. M. Forester. Eng. News-Record, 111: 275–9, 1933. The 2-m.g.d. water purification plant constructed to render Colorado River water suitable for consumption in Boulder City, Nevada, consists of pre-sedimentation units near river and filtration and softening plant in city. Treatment plant was designed for aëration, sedimentation, excess lime-soda softening, coagulation, carbonation, and filtration. In general, best results are obtained when sufficient lime is added to give caustic alkalinity of 40–55 p.p.m. and sludge is returned from primary sedimentation basin to primary agitators for recirculation. During one period following

heavy storms, when the water contained an unusual amount of very fine suspended matter, addition of sufficient lime to give a caustic alkalinity of 250 p.p.m., followed by carbonation, was found effective in removing the colloidal material. Use of soda ash was discontinued during this period as it was found to retard floc formation. Although turbidity of raw water has been as high as 150,000 p.p.m., and suspended solids, as high as 84,400 p.p.m., total hardness varying from 100 to 904 p.p.m., a clear water with hardness of about 100 p.p.m. has been delivered to consumers almost consistently. Excess lime treatment effectively sterilizes water, but as precaution, chlorination is also employed. As Boulder City, which is construction camp for Boulder Dam project, is 6.6 miles from, and 2000 feet above, river, 3 pumping lifts are necessary. Water may be drawn from 7 intermediate points between high and low water level by means of centrifugal pumps mounted on carriage which can be raised or lowered on an incline.—*R. E. Thompson (Courtesy Chem. Abst.).*

Elevated Tank in Lindsay, Ontario, Improves Water Service and Reduces Operating Costs. Eng. and Contract Record, 47: 768–9, August 9, 1933. Supply system of Lindsay consists of 2 intakes in Scugog River, settling basin, and 5 mechanical filters with total capacity of 1.8 m.I.g.d. Three deep wells are under construction which will supply 1.5 m.g.d. The population is 7200 and in 1932 daily average consumption was 650,000 gallons. A 250,000-gallon elevated tank, recently completed, permits discontinuance of pumping during peak power periods, effecting saving of over $500 per year.—*R. E. Thompson.*

Water Softening Practice Shows Rapid Growth. CHARLES H. SPAULDING. Eng. News-Rec., 110: 747–8, 1933. Brief discussion of increasing number of water softening installations and review of recent developments in art of softening.—*R. E. Thompson (Courtesy Chem. Abst.).*

Progress on the New Water Supply for Metropolitan Boston. Eng. News-Rec., 111: 308–9, September 14, 1933. Brief details given regarding status of project, involving tapping of Ware and Swift Rivers, to furnish additional 194 million gallons per day, more than doubling present supply of District, which includes 20 municipalities with combined population of 1,500,000. Project includes 11- x 12.75-foot tunnel, known as Quabbin Aqueduct, extending 24.6 miles westward from present Wachusett Reservoir; diversion dam and elaborate intake works on Ware River; intake control works at west portal; 2 large earth dams on Swift River and Beaver Brook, which will form new Quabbin Reservoir; and large diversion tunnel at Swift River dam.—*R. E. Thompson.*

Well-Managed Tunneling Methods Whip Low Contract Price. Eng. News-Rec., 111: 310–4, September 14, 1933. Detailed description of methods being employed on construction of 10.6-mile tunnel, last section of aqueduct from Quabbin Reservoir site to existing Wachusett Reservoir. First section of tunnel, extending 14 miles to Ware River, has been completed and is in service: section under construction will extend from Ware River to Swift River to complete aqueduct. Contract price was $4,917,032.—*R. E. Thompson.*

Toronto's New Half-Million Dollar Building for Waterworks Maintenance. Eng. and Contract Record, 47: 757–61, August 9, 1933. Detailed description of recently completed water works maintenance building, 332 x 213 feet, constructed at cost of approximately $500,000 as unemployment relief measure.—*R. E. Thompson.*

Modern Swimming Pool Construction. E. H. DARLING. Can. Pub. Health J., 24: 420–8, 1933. Detailed discussion of design and construction of swimming pools, as exemplified in new pool at Hamilton, Ont. Capacity of circulating pump, filter, and chlorinating apparatus is sufficient to purify pool water 3 times each day.—*R. E. Thompson (Courtesy Chem. Abst.).*

A Million Dollar Water Supply Tunnel for the City of Vancouver. Engineering and Contract Record, 47: 1013–8, November 1, 1933. A description of the pressure tunnel recently constructed under First Narrows of Burrard Inlet to replace system of submerged pipes which had been frequently damaged by dragging of ships' anchors during storms. North shore shaft was sunk to depth of 400 feet. Tunnel, 7.5 feet in diameter and 3104 feet long, was lined with Bonna steel-cylinder-reinforced concrete pressure pipe. Concrete lining, 2 inches thick, was placed centrifugally and concrete covering was poured with pipe in place so as completely to fill space between steel shell, $\frac{5}{32}$ inch thick, and rock. Special cast steel caps were placed on top of shafts, four 48-inch outlets being provided for connections to present and future mains. Tunnel, which has capacity of 200 m.g.d., was tested for 48 hours at pressure of 210 pounds per square inch with satisfactory results. A 4750-foot all-welded steel pipeline, 6 feet in diameter, was constructed through Stanley Park to connect tunnel with city distribution system and 4000-foot line on north shore to connect with existing pipelines. Cost of tunnel was approximately $1,000,000 and of Stanley Park pipeline, $250,000. After some years, impounding reservoir will be created on Capilano Creek which will increase available supply from that source to about 200 m.g.d. Present consumption averages 34 m.g.d., with maximum of 65 m.g.d.—*R. E. Thompson.*

Flow of Water Around Bends. JAMES W. PEARL. Eng. News-Rec., 111: 570, November 9, 1933. Brief mathematical discussion of flow of streams around bends.—*R. E. Thompson.*

How to Combat Short Filter Runs. NORMAN J. HOWARD. Eng. Contract Record, 47: 945–6, 1933. Short runs are usually associated with fine filter sand, microscopic organisms in applied water, or inadequate preparation of water for filtration. Trend of modern practice is toward employment of coarser sand in rapid filters. Wide variations in bacterial removal were not observed in experiments carried out at Toronto using sands ranging in effective size from 0.25 to 0.65 mm. Correct dosage of coagulant and adequate mixing are important. Introduction of artificial turbidity has facilitated coagulation at many plants. Short filter runs due to microscopic organisms have never been experienced with drifting sand filters at Toronto.—*R. E. Thompson (Courtesy Chem. Abst.).*

Operating Costs Reduced for Supplying Water to the City of Windsor, Ontario. G. C. Storey. Engineering and Contract Record, 47: 849–51, September 6, 1933. Water works system operation during 1932 showed profit of $22,727.28. Outstanding debentures at close of year totaled $1,419,000. Per capita costs during past 44 years are given. Operating costs during year averaged $1.62 per capita, including city's share of operating expense of filter plant (Essex Border Utilities Commission) which was $0.47 per capita. Average daily pumpage was 6.57 million gallons, including 1.38 sold to suburban municipalities, per capita consumption being 85 gallons per day. Over 99 per cent of services are metered. Underground leakage was reduced by surveys. Services 2 inches and under in diameter are of copper. Customer accounting system is being changed from roll book method to ledger cards.—*R. E. Thompson.*

Cost of Making Alum at Kansas City. Eng. News-Rec., 111: 557, November 9, 1933. Cost of manufacturing 5,308,110 pounds of alum during year May 1931–April 1932 at Kansas City, Missouri, water works was $42,707, including materials, labor, interest, and depreciation.—*R. E. Thompson.*

Chlorination and Dechlorination of Drinking Water. W. Plücker and H. Gautsch. Zeitschrift für Untersuchung der Lebensmittel, 66: 62–81, 1933. From Chemistry and Industry, 52: 52, 1088 B, December 29, 1933. From 0.05 to 0.2 p.p.m. of free chlorine, acting for one hour, is more effective against *B. coli* than either sodium hypochlorite, or chloramines, at equivalent concentration. In presence of 0.01 p.p.m. of silver, as silver nitrate, 0.05 p.p.m. of chlorine is effective in fifteen minutes, and similar results are obtained with 0.01 p.p.m. of copper, as copper sulphate. Neither silver nor copper is effective unless water filtered. Chlorine adsorbed on charcoal filters is best removed by aqueous ammonia. Peat can replace charcoal in filters and manganese in peat catalyses chlorine to hydrochloric acid. Little infection or disinfection takes place during filtration of water through peat.—*W. G. Carey.*

Importance of Ammonia in the Chlorine Consumption of Water. M. L. Koschkin. Zeitschrift für Hygiene, 115: 99–109, 1933. From Chemistry and Industry, 52: 32, 654 B. August 11, 1933. Increased bactericidal action of chlorine produced by pre-treatment with ammonia occurs because ammonia reduces chlorine consumption by combining with substances present in the water, decreasing the chlorine demand. This action is particularly marked in waters containing phenol, and prevention of chemical taste and odor frequently depends on thus reducing chlorine consumption. If ammonia is added simultaneously with, or subsequently to, chlorine, no effect on taste is observed.—*W. G. Carey.*

The Rapid Elimination of Oxygen from Water, or Aqueous Solutions. K. B. Mears and U. R. Evans. Chemistry and Industry; 52: 42, 349–350T, October 20, 1933. Sample is saturated with carbon dioxide, or nitrogen, and exhausted in vacuo, resaturation and exhaustion being continued until oxygen concentration is sufficiently low. Oxygen content of 5.65 cc. per litre was reduced in 16

minutes to 0.117 cc., after 4 evacuations of 2 minutes and 4 saturations of 2 minutes with carbon dioxide, as compared with reduction to 0.163 cc. in 25 minutes, by boiling and cooling.—*W. G. Carey.*

An Apparatus for the Rapid Estimation of Oxygen and Other Gases Dissolved in Water. R. C. HOATHER. Chemistry and Industry, 52: 34, 689–690, August 25, 1933. Gases are expelled by boiling in 500 cc. Pyrex flask under slightly reduced pressure and are collected, measured, and treated with absorbents in micro-burette over mercury. Flask is fitted with rubber stopper, which carries side tube with rubber joint and clip, delivery tube to mercury trough, and short tube to connect with sampling pipette. Air is eliminated by introduction of ordinary water through side tube and boiling for about 15 minutes. Sample is introduced while steam is issuing, and volume of gas evolved into micro-burette is read after cooling and again after introduction of absorbent, e.g., pyrogallol. Reagents can be admitted to sample immediately on collection to prevent unwanted reactions, e.g., potassium iodide when sulphite is present. Evolution of carbon dioxide can be prevented by addition of caustic soda to sample.—*W. G. Carey.*

Approximate Determination of Sulfate in Drinking Water. L. W. WINKLER. Pharmazeutische Zentralhalle, 74: 319–320, 1933. From Chemistry and Industry, 52: 32, 654 B, August 11, 1933. Ten cc. of sample is treated with 2.5 cc. of 10 percent hydrochloric acid and 5 cc. of 10 percent barium chloride. If turbidity appears after measured interval of more than 5, but less than 15, seconds, sulfate content is read from table; if time interval is longer or shorter, a smaller or greater quantity of hydrochloric acid is used with new sample, and separate table is employed.—*W. G. Carey.*

Determination of Nitrates in Water by Indigo. O. MAYER. Zeitschrift für Untersuchung der Lebensmittel, 66: 193–200, 1933. From Chemistry and Industry, 52: 52, 1088 B, December 29, 1933. Five cc. of water are treated with 1 drop of solution containing 5 percent each of mercuric chloride and sodium chloride, 6 cc. of sulphuric acid are added and mixture is titrated with 0.032 percent indigotin in 10 percent sulphuric acid, until blue or green tint persists for five minutes. If more than 3 cc. of indigotin are required, water is appropriately diluted.—*W. G. Carey.*

The Effect of Domestic and Industrial Wastes on the Oder between 1877 and 1932. EGGER. Ges.-Ing., 56: 15, 169, April, 1933. Official stream control in Breslau dates back about 50 years. Examination of the accumulated data makes it possible to determine extent of change in water of the Oder. Biological findings show little difference. Plankton are essentially mesosaprophytic to oligosaprophytic. Change evident from chemical data is, however, confirmed by presence of certain varieties of algae and of a typical brackish water polyp, *Cordylophora caspia,* which is found only in waters of higher chloride content. As judged from water level data, there is no correlation between runoff and dissolved solids. Increase in dissolved matter during high water periods can be explained by the many barriers to flow in shape of weirs and

the frequent sharp crests of the flood waters. During the period of observation there had occurred an increase in dissolved solids and in oxygen consumed and a still more marked increase in chloride content which cannot be ascribed to domestic sewage, namely that of city of Breslau, but is due to industrial wastes. Higher chloride content, especially, is due to high sodium chloride content of upper Silesian coal, which is thoroughly washed before coking. —*Manz. Translated by Selma Gottlieb.*

Central Hot Water Supply for Group Dwellings. P. DREXLER. Ges.-Ing., 55: 25, January, 1932. Cost of installing central water heating system is as great as that of gas heaters to the individual householder. Tap water temperature, heat loss in supply pipes, usually not insulated, and rate of consumption are of importance in determining operation costs. With low consumption, gas is cheaper; with normal, or higher, consumption, coke is more economical. Since heat losses are considerably greater at higher tap water temperatures, latter should be held as low as possible by automatic control. This can be done with three-way valve, which, at higher boiler temperatures, allows some cold water to flow into system, or, if consumption is low, by-passes circulating water into the pipes. When consumption is very low, only enough water is taken from boiler, which is heated to a high temperature, to keep circulating water, which is mixed by the pumps, at desired temperature.—*Manz. Translated by Selma Gottlieb.*

The Nephelometric Determination of Sulfates in Drinking Water. HERM. MOHLER. Zeitschr. f. anal. Chem., 92: 1–2, 15, 1933. Method is suited for rapid determination of sulfate content of numerous samples. To obtain finest-grained precipitate of barium sulfate, precipitation is carried out in cold, with addition of acid. To compensate for increase in solubility product caused by the acid, highly viscous substance is added, increase in viscosity decreasing rate of settling. To 20 cc. of water are added 0.5 cc. of 10 percent hydrochloric acid, 5 cc. of 10 percent barium chloride solution, and 1 cc. of 1 percent gum solution. After 5 minutes, turbidity is compared with that of standards. With a sulfate content under 30 p.p.m. of calcium sulfate, the results agree within 1 to 3 p.p.m. with results of gravimetric determinations.—*Manz. Translated by Selma Gottlieb.*

Water Softening. CURT LUCKOW. Zeitschr. f. Spiritusindustrie, 56: 10, 49, March, 1933. In manufacture of spirits, brandies, etc., properly softened tap, or well, water can be used instead of distilled water. Spirits made with hard water develop turbidity and slime formation even after repeated filtration. Lime and soda ash can be used for softening. Less than calculated amounts of chemicals are added, so that softening is incomplete and water is not made alkaline. Permutit softening, or electro-osmosis method, can be used; with latter, salt content of water can be varied as desired, to suit manufacturing requirements.—*Manz. Translated by Selma Gottlieb.*

Experiences in the Hygienic Control of a Swimming Pool Equipped with a Chlorine-Silver-Copper Sterilization System. ADOLF BECK. Arch. f. Hyg.

u. Bakt., 109: 3, 189, December, 1932. For efficient sterilization, from 0.15 to 0.20 p.p.m. of free chlorine in middle of pool is sufficient, standard being water containing not over 200 bacteria per cc. and no *B. coli* in 100 cc. This excess of chlorine was easily and uniformly maintained with the chlorine-copper method, when about 187.5 grams of chlorine was added per 100 bathers. Filter effluent contained no free chlorine; 10- to 100-fold increase in bacterial count and rise in coli titer occurred during passage through filter. Only with chlorine-copper method was filter effluent free from *B. coli*. Bacterial growth in filter could not be permanently removed by strong chlorination during back-wash. With properly adjusted pool water, increase in bacterial count can be made negligible, the filter then acting primarily to clarify the water and to remove chlorine-absorbing substances. After refilling of pool, content of organic matter increases rapidly when chlorination is discontinued; but falls to normal value in the course of one day of chlorination. During one period, chloride content increased ten-fold and nitrate fourteen-fold; but no appreciable amounts of ammonia and nitrite could be detected.—*Manz. Translated by Selma Gottlieb.*

The After-Softening of Boiler Feed Water with Phosphate during Water Purification. W. Wesly. Beihefte z.d. Zeitschr. d. Vereins deutscher Chemiker, 1: 1933, 8 pp. Describes experiments on small scale, with both standing and flowing water, as well as plant-scale work with view to determine how much of hardness remaining, after pre-softening of boiler feed water with usual chemicals, is removed by phosphate treatment. Addition of phosphate gives greater decrease in residual hardness than its equivalent of alkali. While alkali causes gradual decrease in hardness over long reaction time, maximum softening with phosphate is practically complete after one hour. Beneficial action of phosphate on softening decreases with increasing excess of alkali; with small excess, significant lowering of hardness results, but, with large excess, scarcely any softening occurs. With sufficient alkalinity of the pre-treated water, phosphate can be added to the water in any desired form. In large scale tests in the Oppau and Ludwigshafen works of the I. G. Farbenindustrie, calculated amount of phosphate was allowed to react for about seven hours at 90 to 95° on water pre-softened with lime and soda ash for about 17 minutes, with resulting reduction of hardness from 2.8 to 2.1 p.p.m. In a second case, pre-softening was done with soda ash, caustic soda, and boiler blow-down, with one hour of reaction time; 2½ hours of reaction with phosphate reduced residual hardness from 5.2 to 3.8 p.p.m. From these results it seems best to add the phosphate in course of purification after precipitation of most of hardness by usual chemicals, rather than after completion of softening process.—*Manz. Translated by Selma Gottlieb.*

Radium-Containing Ores and Mineral Waters in Germany. E. Kohl. Ztschr. f. Kurortwissenschaft, 2: 9, 562, December, 1932. The probability of finding radioactive ores in Germany is small. Radioactive waters are of greater significance. Strongly radio-active springs noted are Bad Oberschlema (up to 13500 M. E., in granite contact area), Bad Brambach (up to 2000 M. E., in granite contact area), Bad Landeck (up to 206 M. E., in gneiss),

Bad Kreuznach (171 M. E., from porphyry), and twenty more springs with more than 100 M. E. in granite district of Saxony. All other springs and mineral waters contain less than 100 M. E. In Bad Kreuznach there forms in the salt works a so-called radiobarytes which is highly radioactive, so that it can be worked up for radium salts. A considerable quantity of this deposit is obtained yearly at no additional cost.—*Manz. Translated by Selma Gottlieb.*

Tunnel Construction. Colorado River Aqueduct. F. E. WEYMOUTH. Civil Engineering, 4: 5, 241, May 1934. Main aqueduct includes 29 tunnels, totaling 91.34 miles. Estimated cost of project is $209,402,000. Aqueduct will have maximum capacity of 1,605 cubic feet per second. In February 1934, advance of 3.14 miles was made, so that on March first tunnel excavation was 16½ percent complete. Utilities, including highways, power lines, telephones, water supplies, and fully equipped construction camps have been installed. With few exceptions, tunnels are in granitic rock; remainder being in sand and gravel. Thirteen separate contracting firms are doing the work, whose mutual rivalry is resulting in the greatest economy and expedition. For example, to save just half a minute switching empty muck car into place at tunnel heading, ingenious devices, such as vertical-lift "cherry picker," have been developed.—*H. E. Babbitt.*

Discharge Coefficients for Pipe Orifices. W. M. LANSFORD. Civil Engineering, 4: 5, 245, May 1934. Results of eight investigations collated. In measuring discharge from certain pipe lines, convenient piece of apparatus is an orifice in cap fixed over end of pipe. Similarly, measurement can be made at any point in pipe line by insertion of diaphragm containing orifice. When loss of head through orifice and diameters of pipe and of orifice are known, experimentally determined coefficient may be applied to calculate the flow. Many experimenters have worked on problem of determining proper value of this coefficient for given conditions. By examining data of many of these experiments and reducing them to common basis, it is possible to show remarkable agreement of the results obtained.

Priest Dam on the Hetch Hetchy Aqueduct. M. M. O'SHAUGHNESSY. Civil Engineering, 4: 5, 248, May 1934. Construction and maintenance experience with rock- and hydraulic-fill structure. Articulated concrete core wall is unusual feature of this dam. It was expected that, during construction and subsequent consolidation, unbalanced pressures on core wall would slightly displace it. Lest rupture thus ensue, wall was divided into panels; vertically, by deflection joints of ball and socket type, spaced 50 feet on centers, and horizontally, by contraction joints, 16 feet apart. All joints were sealed with copper strips. Since completion, loose rock-fill, downstream from core wall, has settled 9 feet; earth on upstream side, placed by hydraulic methods, has settled 2½ feet; and core wall has deflected downstream to maximum of 2½ feet. For past ten years, leakage through the dam has been measured by weirs and has been found to be nearly constant at one-third cubic foot per second.—*H. E. Babbitt.*

Flow Around A River Bend Investigated. F. L. Blue, L. K. Herbert, and R. L. Lancefield. Civil Engineering, 4: 5, 258, May 1934. Studies were made at bend in Iowa River near Iowa City. Super-elevation of water-level at outside of bend was determined by actual measurement and theoretical formula for same was developed, based on centrifugal force, showing reasonably close agreement with observation. It is concluded that spiral flow exists around river bends, this adding weight to theory first advanced by Professor Thomas, in England, in 1876.—*H. E. Babbitt.*

Boston's New Metropolitan Water Supply. F. E. Winsor. Civil Engineering, 4: 6, 283, June 1934. Expansion of historic system requires solution of legal, hydraulic, and construction problems. Admittedly fourth in point of population, Metropolitan District of Boston probably leads all others in number of politically independent units embraced. Within ten miles of Massachusetts capitol are 35 cities and towns, each having its own separate government. Boston itself contributes only 800,000 of total population of 1,900,000 in District. History of development is brought down to date, starting with well-known Connecticut River diversion case. Construction is now progressing on 25-mile tunnel connection with older Wachuset system, including construction of spiral-lined shaft 260 feet deep, capable of diverting 2 billion gallons per day from Ware River, and of two large earth dams, with articulated concrete cores, sunk 130 feet into ground water. By completion of these dams, expected in 1940, will be formed the Quabbin reservoir. Total expenditure will be $65,000,000, of which $27,000,000 had been expended up to March 1, 1934.—*H. E. Babbitt.*

Concrete for Madden Dam. I. E. Burks. Civil Engineering, 4: 6, 289, June 1934. History of theory and practice in proportioning and placing of concrete is traced from 1900. It is concluded that water-cement ratio provides most satisfactory basis for designing concrete mixtures yet proposed. In specifications for Madden Dam, no definite method of proportioning the materials is stated. Usual requirements for quality of materials are inserted and matter of grading is covered by brief paragraph. Minimum 28-day compressive strength for mass concrete is fixed at 1,500 pounds per square inch and, for reinforced members, at 3,500 pounds. Methods for meeting these requirements, control of mixing, and test procedures followed are explained. Procedure followed, using water-cement ratio for the mortar and trial method for proportioning the coarse aggregates, has proved to be simple and workable and to produce satisfactory results.—*H. E. Babbitt.*

Constructing the Bouquet Canyon Pipe Line. H. A. Van Norman. Civil Engineering, 4: 6, 306, June 1934. Large all-welded conduit in rough country serves a dual purpose, an unusual feature of Bouquet Canyon reservoir, recently completed, being that up to 33,000 acre-feet of water from Owens River Aqueduct can be conducted to it for storage and withdrawn again as needed through same pipe. Located in unbelievably precipitous country, this 3-mile pipe line includes one inverted siphon with static head of 870 feet, laid on slopes well over 100 percent. Pipe is from 7 to 8 feet in diameter, arc-welded throughout,

is supported on concrete and structural steel piers, and is carefully coated inside and out with protective paint selected after many comparative tests. Outside priming coat of synthetic red paint was found to reduce maximum temperature inside pipe during construction by about 30 degrees; enough to make conditions bearable for field welders in summer. Special steel carriages straddling the pipe line were developed by city's engineers and greatly facilitated field erection. Water was turned into conduit on March 28, 1934.—*H. E. Babbitt.*

Differential Two-Liquid Gages and Specific Gravities. E. W. Schoder. Civil Engineering, **4**: 6, 266, May, 1934. Errors resulting from unguarded use of various liquids are discussed. For example, factor required for kerosene above water columns is about 4 per cent greater than its known specific gravity would indicate.—*H. E. Babbitt.*

Graphical Solution for Hydraulic Jump. G. H. Hickox. Civil Engineering, **4**: 5, 270, May 1934. Charts are presented for solution of the problem.—*H. E. Babbitt.*

Review of Piping Standardization Shows Vast Amount of Work Done. Sabin Crocker. Industrial Standardization, **5**: 3, 48, March 1934. More progress has been made during past 15 years than is represented by the aggregate of preceding years. Seven years intensive work by Sectional Committee on Code for Pressure Piping (B31) will be culminated by publication of American Standard Code for Pressure Piping soon to be submitted to American Standards Association for approval.—*H. E. Babbitt.*

Large Diameter Cast Iron Pipe Line for Bayonne, N. J., Water System. The U. S. Piper, **7**: 2, 19, June 1934. Outline of development of Bayonne water supply system is given, with particular emphasis on use of cast iron pipe. New pipe line is 42 inches in diameter, 6,000 feet long, and is estimated to cost $115,000.—*H. E. Babbitt.*

Water for Sanitary Uses with Non-Payment of Water Bills. H. F. Ferguson. Illinois Health Messenger, **6**: 11, 76, June 15, 1934. Procedure consists in placing metal disc in union on city side of water meter with very small hole in disc, capable of allowing water to flow into house water supply system at very slow rate.—*H. E. Babbitt.*

Some Methods for Tracing the Flow of Ground Water. Johnson National Drillers Journal, **6**: 2, 1, April–May 1934. Three methods are used: (1) dyes, detectable colorimetrically, (2) soluble salts, detectable by chemical analysis, and (3) electrolytes, detectable conductometrically. Details and operation of each method are explained.—*H. E. Babbitt.*

Pump Operated by Compressed Air. Johnson National Drillers Journal, **6**: 2, 5, April–May 1934. Proposed for deep well pumping.—*H. E. Babbitt.*

Houston Adopts a Cross-Connection Idea Worthy of Note. H. N. OLD. American Journal of Public Health, 24: 6, 586, June 1934. Officials of a bank building were persuaded to abate cross-connections by calling their attention to dire consequences from cross-connections in two Chicago hotels in 1933.—*H. E. Babbitt.*

Water Measurement Symposium Features Higher Accuracy. Power, 77: 13, 688, Mid-December, 1933. Gibson, photo-flow, salt-velocity, and current-meter methods of measuring flowing water. Gibson method, applicable to measurements in closed conduits, is based on hypothesis that magnitude of momentum of flowing water depends upon the velocity.—*H. E. Babbitt.*

Developments and Improvements in a Borough Water Supply. J. A. CARR. The American City, 48: 6, 41–43, June, 1933. Improvements effected in Ridgewood, N. J., water system, since its purchase from private company in 1921, include additions to motive power, pumping machinery, and storage. Pumping plant and newly developed chronoflo water level recorders are discussed. Metering, started in 1923, is now 100 percent. Water is supplied to neighboring boroughs of Glen Rock and Midland Park on basis of annual payment of 0.67 cent per inch diameter per foot length of distribution and transmission mains and of $6.00 for each public hydrant. Method of differentiating between distribution and transmission mains is described.—*Arthur P. Miller.*

Unemployed Labor Used to Increase Water Supply in Bristol, Conn. CARLETON W. BUELL. The American City, 48: 6, 46–48, June, 1933. In view of unemployment conditions it was decided to provide needed additional water by raising one reservoir ten feet, thus more than doubling its capacity. By unique methods adopted, city, while utilizing to the maximum unemployed labor, accomplished a first-class job without excessive cost. Almost 40 percent of money spent was paid to unemployed labor.—*Arthur P. Miller.*

The Place of Powdered Activated Carbon in Water Purification. F. E. STUART. The American City, 48: 6, 49–50, June, 1933. History of activated carbon: its application to incoming water ahead of, or along with, coagulant. Five advantages of this process are pointed out and two proved methods of application are described.—*Arthur P. Miller.*

Pumps and Their Place. L. R. DOUGLASS. The American City, Part I. 48: 6, 62–64, June, 1933. Part II. 48: 7, 41–43, July, 1933. Author classifies pumps as displacement, centrifugal, and air-lift. Displacement types described and briefly discussed include piston, plunger, vertical triple expansion, horizontal cross-compound, crank and flywheel, direct-acting, reciprocating, deep-well reciprocating, and rotary. Centrifugal pumps are of volute, or turbine type and may be single-stage, two-stage, or multiple-stage: their capacities and efficiencies are discussed. Air-lift pump, commonly confined to well pumping, is touched upon and air equipment and eduction lines are described. Very illuminating comparison of different types of pumps, giving advantages and disadvantages of each, is tabulated. Suitability for duty

required, reliability, durability, and economy are bases upon which pumping machinery should be selected.—*Arthur P. Miller.*

A Study of the Water Supply of Staunton, Va. RICHARD H. CATLETT. The American City, 48: 6, 65–67, June, 1933. Historical sketch of Staunton, Va., water supply from year 1748 to present day. New dam and distribution reservoir and other appurtenances are described. Water softening process caused red water trouble at first, but is now functioning satisfactorily. Chlorine is added at two points, namely, at first dam, and at Two Mile Hill reservoir.—*Arthur P. Miller.*

Water-Softening Plants for Small Cities. HOWARD R. GREEN. The American City, 48: 7, 49–51, July, 1933. Cost must be kept low and operation must be simple. If installed only for its convenience, it is a luxury; but, if savings can be shown, it is a matter of economy. In tabular set-up, author shows for fictitious case annual saving per capita of $1.68. Savings are, however, individual, and not municipal, and consequently do not appear as increased income. Article concludes with description of operating difficulties and of costs of construction.—*Arthur P. Miller.*

Clothing the Old Water Tower. E. B. MYOTT. The American City, 48: 8, 43, August, 1933. Appearance of many water towers admirably serving their purposes leaves much to be desired. Usually, moving, or eliminating, tanks or standpipes would be too expensive. This article suggests concealing and beautifying them by building around them observatory of classical proportions made of steel framing and reinforced concrete shot into place under pressure.—*Arthur P. Miller.*

Normal, Illinois, Saves $3,500 Annually in Water Pumping. ALEX. VAN PRAAG, JR. The American City, 48: 8, 48–49, August, 1933. Wells in porous water-bearing stratum of sand, gravel, and boulders at Normal, Illinois, a town of 6800, had such high maintenance and operating costs that they were abandoned. New supply was secured from new well of more scientific construction, under guarantee of minimum production. Large quantities of fine sand were removed and replaced with washed and graded gravel. Savings in power alone approximate $3500 annually.—*Arthur P. Miller.*

A Study of the Frequency of Tastes and Odors in the Philadelphia Water Supply. Anon. The American City, 48: 8, 53–54, August, 1933. Since 1920, Philadelphia Bureau of Water has worked to decrease amount of taste-producing matter entering Schuylkill and Delaware Rivers, the sources of supply. Many industries are located on the Schuylkill, wastes from which, owing to its small flow, constitute menacing problem. Flow of the Delaware is much larger, so that dilution cares for industrial wastes entering it. Article describes method of locating tastes and odors, steps taken at filter plants to eliminate them, and filtration plants themselves. Brief summary of taste and odor survey is given. Experience in this city indicates that slow sand

filtration, preceded by roughing, or pre-filters and/or adequate sedimentation, effectively eliminates objectionable tastes and odors.—*Arthur P. Miller.*

Can We Put More Economy into our Water Works? W. E. MacDonald. The American City, 48: 8, 57–61, August, 1933. Describes various ways in which water works economies can be effected. Among many items mentioned are adoption of centrifugal pumps, installation of distributing systems, elimination of waste water, standardization of water meters, alert supervision of purification chemicals, first aid and safety instruction *vs.* workmen's compensation, cost accounting, and superannuation.—*Arthur P. Miller.*

A Four-Million-Gallon Ornamental Storage Tank. Theodore Reed Kendall. The American City, 48: 9, 39–40, September, 1933. Sheboygan, Wis., has recently placed in service what is thought to be largest elevated steel water tank in municipal service in this country. City pressure will be utilized by it just as though another pumping station had been built at the tank site and it will permit shut-down of pumps for as much as 24 hours. Weight is supported on 52 circular columns, 30 inches in diameter, mushroomed into and supporting 16-inch slab on which tank rests. Column footings are 12 feet x 12 feet x 26 inches. All concrete is reinforced. Tank is masked with surrounding brick curtain wall, pierced with windows to break the façade and furnish light for 3-foot walkway between the tank and wall.—*Arthur P. Miller.*

Solutions of the Problems of Rate Making for Water Service. E. E. Bankson. The American City, 48: 9, 47–50, September, 1933. Discussion of problems, with particular attention to fair cost for public and private fire protection and for transfer from rate to metered service.—*Arthur P. Miller.*

The Effect of Metering on Water Consumption and Water Costs. E. B. Lloyd. The American City, 48: 9, 52, September, 1933. In 1900, when 26 percent of Elgin, Illinois, water services were metered, average daily pumpage per capita was 77.2 gallons and annual revenue per capita was $1.24. In 1930, when 94.3 percent of services were metered, per capita daily pumpage was 63 gallons and annual income $3.21.—*Arthur P. Miller.*

Elevated Steel Water Tank Houses Complete Aëration System. Anon. The American City, 48: 9, 54, September, 1933. Elevated steel water tank recently completed at Garden City, Long Island, contains complete aëration system, consisting of series of trays suspended from roof trusses in such manner that all incoming water pours over trays before entering storage space. Ventilators in top of the tank and in upper part of roof are provided for air intake and for discharge of air and gases.—*Arthur P. Miller.*

Developments in Pipe Joints. R. L. Holmes et al. American Railway Engineering Association, 35, Bul. 362, 625–637, 1933. Very comprehensive review is submitted complete with illustrations showing all available types of joints for wrought iron, steel, cast iron, and composition pipe.—*R. C. Bardwell.*

Gravel Wall Wells Reduce Cost. C. R. KNOWLES. Railway Engineering and Maintenance, **30:** 1, 69–70, 1934. Illinois Central Railroad has reduced cost of providing, and materially improved quality of water at Grenada, Miss., through development of two gravel wall wells 184 feet deep. Static level of water is 8 feet below ground surface and draw-down is only 1 foot per 50 gallons per minute yield. Wells are operated automatically with 12-inch, 4-stage, vertical centrifugal pump at 22-foot setting with 20-foot suction pipe. Pumps are driven by 10-H.P. direct connected motors. Test shows power consumption of only 0.4 kwh per 1000 gallons water pumped.—*R. C. Bardwell.*

Records Show Value of Water Treatment. E. L. E. ZAHM. Railway Age, **95:** 22, 760, 1933. Missouri, Kansas, and Texas Railroad has 72 water treating plants, all of continuous type using lime, soda ash, and sodium aluminate. Water treatment has greatly increased locomotive mileage between shoppings and has practically eliminated engine failures due to water conditions. Extension on tube renewals has been allowed by the Federal Inspection Bureau on 22 percent of locomotives in service and fuel consumption in freight service has been reduced 31 percent.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Large Water Treating Plant Embodies New Features. R. E. COUGHLAN. Railway Engineering and Maintenance, **29:** 9, 418–420, 1933. Chicago and Northwestern Railroad recently placed 2.5-m.g.d. water treating plant in service at Clinton, Ia. Mississippi River water is used, varying from 7.14 to 11.99 grains per gallon in incrusting solids and from 19.68 to 624.27 in suspended solids. Water is treated at rate of 100,000 gallons per hour with lime, soda ash, and sodium aluminate. Compressed air is used for mixing and sludge is recirculated. Operation is automatic. Softened water has hardness less than 1.0 grain per gallon and pH of 9.8 to 10.2.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Cause and Extent of Pitting and Corrosion of Locomotive Boiler Tubes and Sheets. J. H. DAVIDSON et al. American Railway Engineering Association, **35:** Bul. 362, 623–624, 1933. Experience indicates that most practical method for reducing pitting and corrosion is to provide caustic alkalinity in boiler water equal to from 10 to 15 percent of Na_2SO_4 and NaCl present.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Methods and Value of Water Treatment with Respect to Estimating and Summarizing Possible Savings Effected. R. E. COUGHLAN et al. American Railway Engineering Association, **35:** Bul. 362, 624–625, 1933. Material reduction has been made in boiler repairs and periods between boiler washings have been extended.—*R. C. Bardwell (Courtesy Chem. Abst.).*

Effect of Various Amounts of Sodium Fluoride on the Teeth of White Rats. H. TRENDLEY DEAN, W. H. SEBRELL, R. P. BREAUX, and E. ELVOVE. Public Health Reports, **49:** 37, 1075–1081, September 14, 1934. Sodium fluoride content of 25 p.p.m. in drinking water of white rats produces teeth changes manifested by minute, transverse, brown striations. Striations become more

pronounced as sodium fluoride content is increased to 50, 75, and 100 p.p.m. With (1) 150 p.p.m., striations become irregular brown patches; (2) 300 p.p.m., teeth become creamy in color and tend to fracture; striations not being seen; (3) 500 p.p.m., some animals die, while survivors' teeth become white, chalky, and very brittle. Addition of 5 percent of calcium carbonate to the diet failed to cause any appreciable change in gross appearance of teeth of rats using drinking water with sodium fluoride contents of 50, 150, and 500 p.p.m. respectively. Fluoride ingested in drinking water of 500 p.p.m. fluoride content exhibited under the conditions of these experiments relatively greater toxicity than the same amount in the diet. 4 tables, 1 chart.—*R. E. Noble.*

Effectiveness of Filtration in Removing from Water, and of Chlorine in Killing, the Causative Organism of Amoebic Dysentery. BERTHA KAPLAN SPECTOR, J. R. BAYLIS, and O. GULLANS. Public Health Reports, **49**: 27, 786–800, July 6, 1934. *Endamoeba histolytica* cysts are removed completely from water by coagulation and filtration through rapid sand filter beds. The amount of chlorine, or of chloramine, required to kill the *Endamoeba histolytica*, or *coli*, cysts, is much more than could be used in a public water supply. Chlorine is more effective than chloramine in killing the cysts. *Endamoeba coli* cysts have no greater resistance to chlorine than *histolytica* cysts. 13 tables.—*R. E. Noble.*

Prosecution for Polluting Waters Dismissed Because of Insufficiency of Complaint. Public Health Reports, **49**: 31, 920, August 3, 1934. (Texas Court of Criminal Appeals; LESTER *v.* State, 71 S.W. (2d) 278; decided May 2, 1934.) Article 698 of Texas Penal Code penalizes one who shall pollute any water course, etc., by depositing or discharging therein, "or in such proximity thereto that it will probably reach and pollute the water" thereof, any crude petroleum, oil, sewage, etc. In a prosecution thereunder in which there was a conviction for polluting a water course and lake, the information did not follow statute quoted above, but stated: "Cast crude petroleum and oil in proximity to such water course that such crude petroleum and oil reached such water course." Appellate court dismissed prosecution.—*R. E. Noble.*

Experiences on an Industrial Scale Respecting the Clarification of Turbid Waters from Coal Washeries. W. PETERSEN. Glückauf, **70**: 125–131, February 10, 1934. Experiments in the Ruhr have shown that small quantities of 2 percent solution of potato starch, added to turbid waters from coal washeries, will clarify them, so that they may be reused. Water from the washing of coal high in oxygen requires more starch than water from lower oxygen coals.—*R. DeL. French.*

The Law on Water Rates. LEO T. PARKER. Water Works Eng., **87**: 2, 71, January 24, 1934. Courts have ruled that preferential rate may be given some consumers, if said rate is not proven damaging to other consumers. Generally speaking, higher court will not disturb, or reverse, water rate decision rendered by Public Service Commission, if it does not infringe any constitutional right of the parties. When municipality furnishes water to its

inhabitants, it acts in capacity of private corporation, and not in exercise of its power of local sovereignty. Water rates are not taxes, because no one is compelled to receive, use, or pay for water, except at his own request. Owner of real estate is under no obligation to furnish water to tenant, unless he has contracted to do so, or State legislature has passed law which makes property owners liable for payment for water used on their premises. Municipality, or water corporation, has right to cut water off for failure and refusal of consumer to pay past due indebtedness. In case of controversy, where consumer's offer to pay part was rejected by corporation, water company is liable in damages. —*Lewis V. Carpenter.*

Final Section of Hetch Hetchy Water Supply Tunnel Holed Through. Anon. Water Works Eng., **87**: 2, 84, January 24, 1934. It is expected that by next spring gravity supply from mountains 167 miles away will begin to flow into Crystal Springs Lakes. Most of remaining work will consist in lining tunnels. Hetch Hetchy is designed to furnish 400,000,000 gallons daily to San Francisco. System contains two tunnels, with length of 28 miles, much of it in quick sand. Work is now in charge of Public Utilities Commission, with city as low bidder on the construction.—*Lewis V. Carpenter.*

Pumping Stations Can Be Made Attractive. C. P. Harnish. Water Works Eng., **87**: 3, 110, February 7, 1934. In five cases in California, water companies employed architects to design exteriors of small pumping plants. In several cases, small storage reservoirs were also enclosed as part of station. Illustrations of the five designs are given.—*Lewis V. Carpenter.*

Water Rights of Cities. Leo T. Parker. Water Works Eng., **87**: 3, 113, February 7, 1934. Any person, or corporation, may acquire prescriptive right to use a definite quantity of water from source of water supply, if such person, or corporation, has continuously used this quantity of water over period of years. Even if water has been used for power, it is not possible to disregard this law for municipal purposes. City using an average of 500,400 g.p.d., but on some days 820,000 gallons, has prescriptive right only to average quantity. Courts have held that flood water may be appropriated only when riparian owners do not, or cannot, use them for reasonable beneficial purposes. Courts have consistently held that if property owner creates lake upon his own premises for his own purposes, he can prevent public use of such waters. It is well established law that citizen who files suit against city to recover damages for injury or loss, is bound to prove that such injury or loss was actually caused by negligence of authorized municipal officials or employees; otherwise, jury will render verdict in favor of city.—*Lewis V. Carpenter.*

Water Level Indicating Device Measures Minimum Night Flow. Maurice B. Frost. Water Works Eng., **87**: 3, 116, February 7, 1934. Author gives working drawing for mercury type level gage with indicating range of from 0 to 125 feet head of water. Three-quarter-inch pipe connects water with top of short 4-inch diameter nipple which is filled with mercury. One-eighth-inch pipe from bottom of mercury well is connected by rubber tubing

with upright glass tubing. Scale is metallic tape, suspended from above, hanging plumb.—*Lewis V. Carpenter.*

The Typhoid Carrier Problem. N. H. Wolpert. Water Works Eng., **87**: 4, 160, February 21, 1934. Carriers have been responsible for much typhoid, particularily from food served at church suppers. It is safe to assume that about 5 percent of those who recover from typhoid become permanent carriers, males and females alike. Women, however, because they handle more food, are involved in more epidemics. All food handlers should be examined for typhoid. Regulations of New York State for control of typhoid carriers are given. After typhoid epidemics, water works operators have to be particularly cautious, because of danger from carriers.—*Lewis V. Carpenter.*

Modernizing an Inefficient Plant. Richard H. Ellis. Water Works Eng., **87**: 4, 164, February 21, 1934. Author describes in detail reorganization of shop records, of meter repairs and records, and of reading and billing procedure, and other general improvements, by means of which it was found possible to turn a deficit into a surplus.—*Lewis V. Carpenter.*

Eliminating Cross Connections. Anon. Water Works Eng., **87**: 4, 177, February 21, 1934. Swinging elbow connection is described, by means of which private supply may be admitted in case of emergency into public supply line. With this arrangement, check valves and other protective devices are unnecessary. Detailed drawing is given.—*Lewis V. Carpenter.*

Washing Silvered Sand after Filtration of Potable Water, and Methods for Increasing Its Oligodynamic Action. S. V. Moisseiev and N. S. Hiller. Jour. Prikladn. Khim., **7**: 205–212, 1934. Cold water is best for washing. Prolonged heating below 100°C., or heating at 180°C. for 1 hour increases oligodynamic effect, because of oxidation of the sand at those temperatures. Tests show that it is desirable to replace simple silvered sand with chloro-silvered sand, which is more efficient and no more costly.—*R. DeL. French.*

Sterilization with Chlorine and Its Compounds a Simple Oxidation Process. Ed. Imbeaux. Rev. Hygiène, **55**: 696–699, November, 1934. Sterilizing power and oxidation potential vary together with: (*a*) acidity of the water, as measured by its pH value: oxidation potential, and, with it, sterilizing power decrease as pH value increases; (*b*) proportion of ammonia added in ammoniation, or chloramination: oxidation potential and sterilizing power decrease as proportion of ammonia increases; (*c*) turbidity: increased turbidity decreases both oxidation potential and sterilizing power; and (*d*) temperature: between 0° and 25°C., both potential and sterilizing power increase with temperature.—*R. DeL. French.*

Pollution of Lake Colac. Discussion at Council. Australian Munic. Journal, July 31, 1934, pp. 35–36. Pollution of Lake has caused annoyance. Sand has become covered with black slime. Extensive weed growths and disagreeable odors have been noted. Conditions are blamed on sewage dis-

charges. Deposits are described and weed growths classified. Government chemist testifies to putrefaction near sewage outlet, although B.O.D. of effluent falls within prescribed limits. Waterworks Board hold Sewerage Authority liable for cost of clean-up. It was finally agreed to employ qualified man to supervise and regulate operations.—*E. B. Besselievre.*

Water Divining. W. F. NEVILL. Australian Mun. Jour., November 15, 1934. p. 239. From over 20 years experience of water diviners, author is of opinion that dipping of twig is humbug, but that certain individuals, especially negroes, have capacity to determine location of water. Probably 50 percent of diviners are frauds. Subconscious sense of surface conditions, as evidenced, e.g., by flight of gnats over ground underlain by water, probably plays the most important part. Divination is uncertain and study of geological structures is to be preferred.—*E. B. Besselievre.*

NEW BOOKS

Water Supply Organization in the Chicago Region. MAX R. WHITE. University of Chicago Press, 1934. This monograph discusses water supplies in the Chicago Metropolitan Region defined as the area within 50 miles from the heart of Chicago. This region includes cities and villages in three states, namely, Illinois, Indiana and Wisconsin.

The author has made a comprehensive and valuable survey of the water systems in the region, and has brought to public attention many unsatisfactory conditions which have existed over long periods of time. He finds that the responsibility for supplying water in the Chicago Metropolitan Region is divided among 168 water systems, 208 governments and 1500 officials. Also that effective coöperation among the various governments is lacking, with resultant inferiority of service and waste of funds.

Of special interest is the author's report on water rates in the various cities in the region. These range from 6.8 cents per 1000 gallons net in Chicago, to 72 cents in the city of Aurora. The effect of re-sale of Chicago water purchased by nearby suburbs and sold to their respective citizens or to more distant suburbs, is unique. For instance, the author reports that Chicago sells water to Harvey at 6.8 cents per 1000 gallons, that Harvey re-sells to Posen at 19 cents, the latter retailing this to its customers at 35 cents. Dalton buys water from Chicago at 6.8 cents, sells to South Holland at 24 cents, the latter village retailing it at 50 cents.

The lack of coöperation between village water departments for fire protection services is emphasized by an incident which occurred in March, 1932 in so-called "No Man's Land" between Wilmette and Kenilworth. This incorporated area, having no water system of its own, contracted with these two villages for water supplies. When a fire broke out in a building in "No Man's Land" the Evanston fire department attached their hose to the Kenilworth hydrant and had the flames practically under control when the police officer of the latter village shut off the water, claiming that the contract between Kenilworth and the corporation owning the building was for domestic purposes and not for fire protection, with the result that the fire caused seri-

ous destruction of this building. It is reported that the owners of the building have filed a $250,000 damage suit against the Village of Kenilworth.

The author describes water systems in other metropolitan areas, particularly Boston, New York, Baltimore, Washington, Cleveland, Detroit, Kansas City, San Francisco and Los Angeles. Suggested programs for reorganization to improve water supply conditions in the Chicago metropolitan region are offered, the more interesting of them being an interstate commission between states involved, similar to the Port of New York authority; or a complete unification through a metropolitan government. The author shows that a greater part of the Chicago metropolitan region, from an engineering standpoint, is a potential unit for the purpose of supplying water.

The national and interstate phases of the pollution of the southern end of Lake Michigan are discussed at considerable length.

The monograph is one which will be read with a great deal of interest by water works, public health and civil administrative officials and it is hoped will stimulate action for improvement in the water supply conditions of the Chicago metropolitan area.—*Arthur E. Gorman.*

The Water Problem of Southern California. Ernest L. Bogart. Illinois Studies in Social Sciences, 19: 4. 132 pages. Attempt to formulate economic principles governing utilization of water under conditions of scarcity at once reveals complexity of the problem. This study begins with inquiry into physical conditions which determine supply of water and into efforts to conserve, equate, and divert to certain points limited available supplies. The purely economical aspects of problem center about questions of costs and the classification of uses of water. Political, social, ethical, and other questions are studied, together with coöperation in use of water. Although study is limited to Southern California, conclusions have a general application. In chapter on **Geographical and Geological data** on water supply of region, same are presented, together with discussion of effects of temperature, precipitation, evaporation, run-off, and percolation on underground reservoirs and on water table. During past 30 years, and especially during last decade, there has been a steady lowering of water table in every basin throughout the valley of Southern California. In chapter on **The Engineering Problem, Conserving the Water,** available water supply, methods of ground water pumping, factors affecting surface storage, practices of water spreading, of flood control, and of sewage reclamation, drainage, and importation of water are discussed. It is concluded that in any study of water problem, first answer to the problem must be given by geologist and engineer. The **Agricultural Problem** is treated from viewpoint of needs of irrigation, including water requirements for maximum crop yields. Ninety-six percent of water consumed is for agricultural purposes; 4 percent is for urban purposes. The **Legal Problem** is carefully and interestingly discussed, with citations of important legal decisions. Conclusion is reached that the early *laissez faire* policy, with its minimum of responsibility and supervision, is no longer feasible in a closely settled region, such as Southern California. Under title of **The Economic Problem and the Cost of Water,** it is shown that point of view in this arid region must be quite different from that in more humid regions. In arid regions, water is a scarce

agent, while land, labor, and capital are relatively more abundant. In accordance with well-known economic principle, the source agent, water, is conserved at the expense of the other more plentiful factors.—*H. E. Babbitt.*

Water Supply and Treatment. CHARLES P. HOOVER. Bulletin 211. Published by National Lime Association, Washington, D. C. 6 x 9 inches. Paper. 143 pp. The whole broad subject is covered briefly but in essence, and in such form as to be of interest principally to municipal officials, industrialists, plant operators, and students. The value of lime in water treatment, together with other chemicals and processes commonly employed, is indicated. The several sources of water, methods of treatment by coagulation, sedimentation, and filtration, the functions of treatment, sterilization, taste and odor removal, prevention of corrosion, and water softening, are covered in the first eight chapters. The remainder of the booklet, about 90 pages, is devoted to a more complete discussion of water softening, its economic benefits, the chemistry of the lime-soda ash method and the zeolite method for municipal installations, special methods for boiler feed waters and for other process uses, concluding with a chapter on analytical methods for water and for the testing and specification of treatment chemicals. The text is well illustrated by photographs of modern plants and by line drawings of structural and functional details.—*R. L. McNamee.*

Journal of the Pennsylvania Water Works Operators' Association, Vol. 6, 1934. Papers presented at Annual Meeting, State College, Pa., June 25–27, 1934. 6 x 9 inches. 185 pp. **Address of Welcome.** F. G. HECKLER. 11–12. **Locating Underground Leakage Regularly and Efficiently.** HARRY BARTON. 13–14. Method of gating off sections of distribution system and measuring, or detecting, leakage by sound. **Controlled Coagulation Maintains Filters in Good Condition.** F. W. BOUSON. 15–16. Monongahela R. water, high in acid salts of iron and alumina, is softened by lime and soda ash to 100 p.p.m., coagulated, settled, filtered, and chlorinated. With phenolphthalein alkalinity of 1 to 3 p.p.m. and pH of 7.6, water contained 2 to 15 p.p.m. of aluminum in solution, which formed a heavy mat of aluminum hydroxide on filters and promoted formation of mudballs. Laboratory tests indicated optimum pH for precipitation of iron and aluminum to be 6.9, which, put into practice on plant scale, improved coagulation and restored filters to good condition. Following filtration, clear lime solution is added to raise pH to 7.5. **Inexpensive Ammonia Treatment.** B. H. BROCK. 17–18. Solution of 5 pints of ammonia (water) in 6 gallons of water is fed at rate of 6 gallons per million gallons of water to be treated. **On Softening.** J. F. BRUNNER. 18–20. Conclusions drawn from study of softening of well water of 250 p.p.m. hardness favor lime-soda process in preference to zeolite. **Turbid Water Caused by Design Oversight.** J. Z. COLUMBIA. 20–22. Description of case where settling basin drainage, backed up in plant drain, entered through overflow port into filtered water reservoir. **Cogitations of a Neophyte.** R. H. CRONE. 22–27. Critical observations of newly employed filter operator: bacterial tests yielding results more quickly; better flushing and cleaning; wider use of light-colored paints and finishes and of rustless metals; automatic indicating

and recording water analysis instruments. **Some Observations at the Coatesville Water Works.** W. C. EMIGH. Observed relations between temperature, pH, and alkalinity of an impounded water. **Troubles with Open Reservoir.** J. G. GRIFFITHS. 31–33. Maintenance of 0.15 p.p.m. chlorine residual in 10-m.g. open filtered water reservoir at New Kensington, Pa., has apparently eliminated tad-poles. **Operation of New Filter Plant at Pottstown.** E. K. GRUBB. 33–38. Addition of chemical house with improved handling and feeding equipment and of mixing and settling basins has reduced coagulant consumption by 30 percent, wash water by 80 percent, and power consumption by 25 percent, eliminated mudballs, and lengthened filter runs. **Characteristics of Wells in Limestone Formations.** E. L. KERSHAW. 38–40. Last and best of 4 wells drilled near Shillington, Pa., yielded 230 g.p.m. **Tadpole Infested Reservoir.** P. R. LUTTON. 40–42. Planting of 6-m.g. open basin with 12- to 18-inch bass eliminated trouble. **Iron and Acid Troubles.** H. W. PHARAOH. 42–45. Split treatment with lime removes all iron, up to 8 p.p.m., from raw water at Indiana, Pa., which has maximum acidity of 110 p.p.m., hardness of 425 p.p.m., and iron content of 20 p.p.m. **On Coagulation.** E. B. WAGNER. 45–47. The $1\frac{1}{2}$-m.g.d. filter plant at Downingtown, Pa., treats algae with copper sulphate and tastes and odors with ammonia, and recirculates coagulation basin sludge to produce good floc on filters. **Lime Demand of Acid Waters.** L. V. CARPENTER and G. PYLE. 47–48. Results of tests on 14 waters ranging in acidity from 40 to 865 p.p.m. indicate an average requirement of 4.67 pounds of CaO (6.17 pounds of $Ca(OH)_2$) per m.g. of water treated for each p.p.m. of acidity. **Elements of Coagulation.** G. D. NORCUM. 49–59. Excellent discussion of coagulants, of feeding, mixing, and sedimentation equipment, and of control of coagulation by jar and laboratory tests. **Amebic Dysentery.** J. W. RICE. 60–65. Encysted forms of *Entameba hystolica* withstand heavy chlorination and high and low temperatures and are effective agents in transmitting of disease by water and food. History, morbidity, and mortality of Chicago epidemic of 1933. Dysentery hazards include possibility of siphonage into water supply lines through outlets in plumbing fixtures below overflow level, flooding by sewage of ice and food supplies in low level basements, cross-connections between potable and contaminated water supplies, and pollution of watersheds. Bibliography. **Some First Year Operating Experiences at Easton, Pa.** R. W. HAYWARD, JR. 68–80. Musty tastes were eliminated only by prechlorination at 4 p.p.m. Mudballs were removed by scraping filters and washing with hose, after washing at 24-inch rise had failed. Short circuiting of settling basins was corrected by baffling. **Chemical Character of Ground Water in Pennsylvania.** W. D. COLLINS. 81–88. General statements of types and constituents of waters. **Discussion:** services rendered by Pa. Topog. and Geol. Survey. **Laboratory Control of New York City Water Supplies.** F. E. HALE. 89–119. Three laboratories, at Mt. Prospect, Mt. Kisco, and Ashokan, analyze 25,000 samples annually. Results of special studies of turbidity reduction, chlorination, microscopic organisms, and of efficiency of sewage disposal plants on the watershed are reported and tabulated. **Odors and Tastes in Water Supplies and Methods for their Determination.** M. W. COWLES. 120–131. Technique of several available methods. Application of progressive dilution method to

taste determination and evaluation. Bibliography. **Metering and Meter Maintenance.** GUY MORROW. 132–138. Repair shop at Washington, Pa., handles 35 meters per day during rush with 3 trained men and 2 helpers. **Discussion**: at Wilkinsburg, Pa., 24,000 meters were repaired during 1926–1933 at a cost of \$4.00 to \$5.00 each. **The Frost.** D. J. MCGEEHIN. 139–146. Discussion of problems of frozen mains and services and of methods of thawing in Hazelton, Susquehanna, Clarks Summit, Williamsport, and Wilkinsburg, Pa. **Wasted Water.** H. E. BECKWITH. 147–153. Discovery and repair of leaks is an important factor in postponing necessary enlargement of supply, pumping, and distribution facilities. **The Length of Filter Run with Pennsylvania Anthracite.** H. G. TURNER and G. S. SCOTT. 154–170. Experimental comparison of four sizes of anthracite filter media, of uniformity coefficient 1.21, with Ottawa sand of effective size 0.61 mm. and of uniformity coefficient 1.21, at filter rates of 125 m.g.a.d., and with applied turbidity of 20 p.p.m. showed that anthracite gave longer filter runs. Theoretical mathematical analysis is offered. **Minutes of Business Meeting, Annual Financial Report, and List of Members.** 171–185.—*R. L. McNamee.*

Proceedings, Eighth Annual Conference, the Maryland-Delaware Water and Sewerage Association, Washington, D. C., May 3 and 4, 1934. 6 by 9 inches. A. W. BLOHM, Secretary-Treasurer, 2411 North Charles Street, Baltimore, Maryland. **Development of Washington, D. C., Supply.** P. O. MACQUEEN. 6–10. Interesting historical account of growth of water supply service to the nation's capital. **A Booster Pumping Plant for the Washington Aqueduct.** J. E. CURTIS. 11–13. Capacity of raw water conduits, now, under gravity conditions, inadequate, is being increased by 20 percent by construction of booster pumping station of about 350 m.g.d. installed capacity, built in dam across Dalecarlia Reservoir, which will improve efficiency of Dalecarlia filters and increase storage capacity of all reservoirs. **Hagerstown, Maryland, Sewage Treatment Works.** H. E. RHODES. 14–23. Detailed description and operating results of new activated sludge plant. **Symposium. Water Works and Sewerage Projects under the Public Works Administration.** J. B. GORDON, ABEL WOLMAN, ROY S. BRADEN. R. C. BECKET and HARRY R. HALL. 24–44. Nature and extent of improvements undertaken in District of Columbia, Maryland, Virginia, Delaware, and Washington Suburban Sanitary District. **Economics of Corrective Treatment for Cold Water Corrosion.** E. S. HOPKINS and J. W. ARMSTRONG. 45–66. Treatment of an entire municipal supply, for correction of corrosive tendencies, with lime, increases hardness and thereby burdens domestic user with costs of increased soap consumption and industrial user with cost of additional softening. Nevertheless, this method of treatment is economically justified. Treatment with caustic soda for neutralization of carbon dioxide and for preventing corrosion, without increasing hardness, is not economically justifiable. Corrective treatment of Baltimore supply was started in 1922. Data are given for increase in hardness, increased cost of Zeolite softening in industrial plants, and increased soap consumption. **Discussion**: Data on use of lime, caustic soda, and soda ash for carbon dioxide reduction are reported for industrial water plant at Luke, Maryland, and for municipal plant at Washington, D. C. Oxygen is considered to be more

important factor in corrosion than pH. **Interesting Features of New Purification Works at Burnt Mills, Maryland.** ROBERT B. MORSE. 67–75. Restrictions of space and configuration of site influenced design of water purification plant in form of concentric ring-shaped compartments, central area for pipe and successive larger annular rings for filters, coagulating basin, and filtered water reservoir. Structures are built of steel on circular concrete slab. Discussion questions steel construction, with its possibilities of corrosion and danger of leakage from coagulating basin to filtered water reservoir. **Extending and Modernizing a Rapid Sand Filter Plant at Wilmington, Delaware.** A. J. FEENEY. 76–79. Description of enlargement of 12-m.g.d. plant to 20-m.g.d., with modernizing of control equipment. **Sewerage Improvements for the Annapolis Metropolitan Sewerage District.** R. L. BURWELL. 80–92. Outline of legislation, engineering, and financing of sewerage and sewage disposal improvements. **Surge Troubles and their Prevention in Pump Discharge Lines of Washington Water Supply.** D. M. RADCLIFFE. 93–96. Surges resulting from quick closing of check valves at times of power failure developed pressures up to 175 percent of normal. Three ten-inch, hydraulically operated, rotary plug type relief valves, installed one on each of three lines of respective diameters of 48, 36, and 36 inches, lengths of 12,350, 8,900, and 15,950 feet, and working heads of 110, 220, and 340 feet, have successfully dissipated all surges. **Wrecking Elevated Water Tanks.** CARL HECHMER. 97–101. Details and costs of two methods of wrecking; overturning and dismantling from top downward. **Adsorption and Flocculation as Applied to Sewage Sludge.** A. L. GENTNER. 102–124. Dilution of sewage sludge with water results in large saving of coagulant, due to resulting change in adsorption equilibrium. **Revolving Distributors for Trickling Filters.** W. A. DARBY. 125–132. Description and advantages of revolving distributors.—*Robert L. McNamee.*